Standards Booklet

# Cambridge A/AS Level Physics
Syllabus code 9702



UNIVERSITY of CAMBRIDGE
International Examinations

# Contents

## Cambridge A/AS Level Physics
## Syllabus code 9702

# Introduction

This standards booklet, for International AS/A Level Physics, draws on typical responses given in question papers from the November 2008 session. Examples are given for a selection of questions from each of the four written papers:

**Paper 2** AS Theory
**Paper 31** Advanced Practical Skills
**Paper 4** A2 Theory
**Paper 5** Planning, Analysis and Evaluation

For each paper, sample responses are given for a number of questions. In each case, responses are shown from each of three candidates:

**Candidate A**
This candidate is typical of a student who receives an eventual grade A in the overall International A Level Physics qualification. Although some responses show occasional slips, the standard of knowledge and application of this knowledge is at a high standard.

**Candidate B**
Responses from this candidate, although also very good, fall just short of the standard expected from a grade A student. A consistent understanding of the core knowledge is demonstrated, but the candidate struggles with some of the finer understanding of the implications of the physics that has been learnt.

**Candidate E**
Responses from this candidate demonstrate only just sufficient knowledge to gain an eventual pass mark. The student has clearly gained some understanding and skill from their A Level course, but continues to struggle with some of the basic concepts that have been taught.

In each case, candidates' responses are accompanied with an examiner's commentary, explaining where answers fall short of the standard expected, and giving suggestions for how students' answers could be improved.

The responses shown are genuine answers given by candidates, though in some cases these come from an amalgam of different scripts. The answers have been rewritten, to protect anonymity.

It may be helpful to read this standards booklet in conjunction with the November 2008 mark schemes and Principal Examiner's Report to Teachers—both of which are available from CIE's Teacher Support Site, at **http://teachers.cie.org.uk/**.

## Question 2

A car is travelling along a straight road at speed *v*. A hazard suddenly appears in front of the car. In the time interval between the hazard appearing and the brakes on the car coming into operation, the car moves forward a distance of 29.3 m. With the brakes applied, the front wheels of the car leave skid marks on the road that are 12.8 m long, as illustrated in Fig. 2.1.

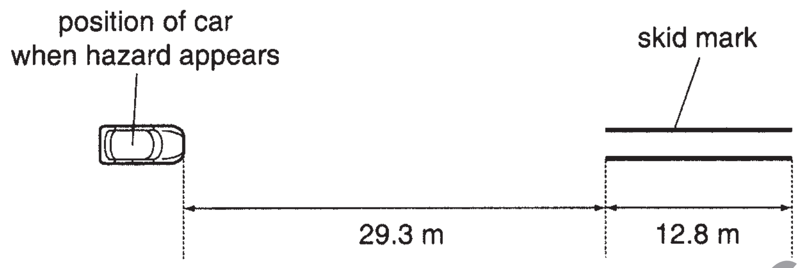



**Fig. 2.1**

It is estimated that, during the skid, the magnitude of the deceleration of the car is 0.85 *g*, where *g* is the acceleration of free fall.

## General comments

**Candidate A**

The candidate demonstrates a clear understanding the equations required for a solution of the numerical parts of the question, ignoring a minor slip in the number of significant figures quoted in the answer to **(a)(ii)**. It is recognised that good candidates can make the odd slip due to exam pressure. The candidate then gives correct answers to two out of three of the points required for the comment section **(b)**.

**Candidate B**

The candidate shows partial understanding of the equations required to solve the numerical parts, but at not quite the same level as the grade A candidate. This candidate correctly identifies the idea of thinking distance.

**Candidate E**

The candidate uses the correct equation in **(a)(i)** but, as with many grade E answers, attempts to use the same equation in **(a)(ii)**. For **(b)**, many grade E answers did not draw correct conclusions from the answers to the numerical parts, or the candidates never attempted this section.

## Specific comments

**(a)** Determine

**(i)** the speed $v$ of the car before the brakes are applied,

***Candidate A***

$v^2 = u^2 + 2as$

$0 = u^2 + 2(0.85)(9.81)(12.8)$

$u = 14.6\ ms^{-1}$

$v$ = ....14.6.............. $ms^{-1}$ [2]

Full marks for a correct answer to an allowed number of significant figures.

***Candidate B***

using $v^2 = u^2 + 2as$

$0 = u^2 + 2(-0.85 \times 9.8)(\text{~~29.3~~} + 12.8)$

$u = \sqrt{\text{~~701.386~~}}$

$= \text{~~26.5~~}\ 14.6\ ms^{-1}$

$v$ = ....14.6 ~~26.5~~.............. $ms^{-1}$ [2]

Full marks for a correct answer to 3 significant figures.

***Candidate E***

$s = 29.3 \quad a = -0.85g$

$v^2 = u^2 + 2as$

$v^2 = 2(0.85 \times 9.81)(29.3)$

$v = \sqrt{(2 \times 0.85 \times 9.81)(29.3)} = 22.1$

$v$ = ....22.1.............. $ms^{-1}$ [2]

One mark for this section. The candidate uses the correct equation but makes a substitution error, entering the wrong distance and so loses the final mark. This wrong value would be carried forward to **(b)** and, provided the candidate made consistent comments, full marks would be awarded.

**(ii)** the time interval between the hazard appearing and the brakes being applied.

***Candidate A***

$s = ut + \frac{1}{2}at^2$

$29.3 = 14.6t + 0$

$t = 2.00\,s$

time = 2.00 s [2]

Full marks for a correct answer, ignoring one minor error in the significant figure calculation.

In general, candidates are allowed to quote answers to plus or minus one significant figure than required by the numbers used. The only occasion when this is not the case would be when a question asks for an answer to a specified number of significant figures.

In this paper, the candidate uses three significant figure values in the calculation 29.3/14.6 which, using the above rule, would allow the candidate to give answers of 2.006 s, 2.01 s and 2.0 s for full marks. The candidate, however, gives an answer of 2.00 s.



***Candidate B***

$v = u + at$

$s = ut + \frac{1}{2}at^2$

$v^2 = u^2 + 2as$

~~$v^2 = u^2 + 2as$~~

~~$14.6^2 = u^2 + 2a(29.3)$~~

~~$a =$~~

using ~~$v = u + at$~~ ~~$s = ut + \frac{1}{2}at^2$~~

~~$29.3 = 26.51t$~~

~~$v^2 = u$~~

$v = u + at$

$0 = 26.5 + (-0.85 \times 9.8)t$

$t = 3.18$

time = 3.18 s [2]

The candidate thinks the car is decelerating in this section, wrong physics, no marks awarded.

***Candidate E***

$s = 29.3$ $\quad s = 12.8$ $\quad a = -0.85g$

$s = \cancel{ut}^{\,0} + \frac{1}{2}at^2$

$29.3 - 12.8 = \frac{1}{2}(0.85 \times 9.81)t^2$

time = 1.99 s [2]

The candidate thinks the car is decelerating in this section, wrong physics, no marks awarded.

**(b)** The legal speed limit on the road is 60 km per hour.
Use both of your answers in **(a)** to comment on the standard of the driving of the car.

***Candidate A***

60 kmhr⁻¹ = 16.7 ms⁻¹. This means that the car has maintained the speed limit. However at 16.7 ms⁻¹, the car's brakes would have come into operation quicker. [3]

The candidate correctly calculates that 60 km/hr = 16.7 m/s. The second mark then requires the candidate to state that this speed is lower than the speed limit; however, the candidate makes use of the words *maintained the speed limit* and has been given the benefit of doubt as compared with *exceeding the speed limit* and has been awarded the mark.

The question asks the candidates to use the two answers in **(a)** and so the final mark was to realise that the answer to **(a)(ii)** was the reaction time and that 2 s was a very slow reaction time. The candidate misses this point and so no mark is awarded. This was a very common error when students answered this question.

***Candidate B***

The car travels at a ~~large~~ slow speed and its thinking distance is large [3]

In this section the candidate is only awarded the mark for a *large thinking distance* equivalent to a slow reaction time. The error in **(a)(ii)** is carried forward and the conclusion is still consistent with the incorrect answer in **(a)(ii)**.

***Candidate E***

Its speed is 60 km/h and the distance is 29.3 m. Its time will be less than the calculated time in (a). [3]

The candidate thinks the car is travelling at 60 km/hr but includes no physics to link this back to **(a)(i)**. The candidate also failed to introduce the idea of reaction time which, if correctly referenced back to the wrong answer in **(a)(ii)**, would gain the mark.

## Question 5

Some smoke particles are viewed through a microscope, as illustrated in Fig. 5.1.

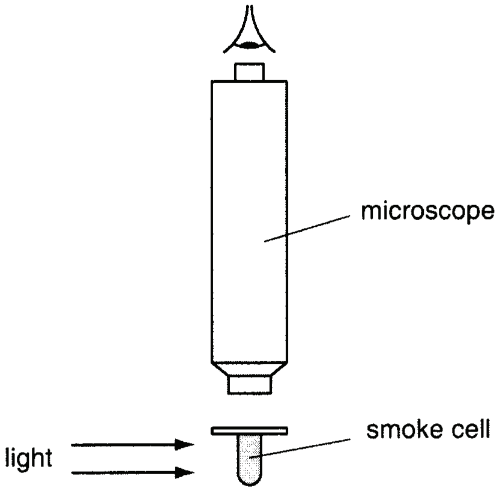



Fig. 5.1

Brownian motion is observed.



### General comments

**Candidate A**

In answering this question, the candidate shows a clear understanding of the interaction between the air molecules and the smoke particles.

**Candidate B**

The candidate is able to display a good understanding of the physics required to answer the first two parts of the question, but is unable to apply this knowledge to generate an answer to the unfamiliar situation in **(c)**.

**Candidate E**

The candidate has a rather vague idea about the random motion of particles, but is unable to see the link between the movement of the smoke particles and the random motion of air molecules.

## Specific comments

**(a)** Explain what is meant by *Brownian motion.*

***Candidate A***

Brownian Motion is the random and continuous motion of smoke particles which are colliding with air molecules. [2]

Full marks obtained as the candidate states that Brownian Motion is the *random motion of smoke particles*.

***Candidate B***

Brownian motion is the random, continuous motion of particles in air. Brownian motion shows evidence for the continuous, random motion of gas particles [2]

Full marks gained for the *random motion of particles in air*. The mark scheme was looking for *smoke* particles but benefit of the doubt has been given by reference to the next section where the idea is that the smoke molecules are moving randomly. The word molecules is ignored.

***Candidate E***

Brownian motion is the random movement of invisible air molecules through smoke particles.

[2]

One mark gained in this section for random movement but then the candidate associates this with *the motion of the invisible air molecules* not the smoke particles.

# Paper 2 AS Theory

**(b)** **Suggest and explain why Brownian motion provides evidence for the movement of molecules as assumed in the kinetic theory of gases.**

***Candidate A***

Since the smoke particles are being collided by air molecules in a hap-hazard way, it means that air molecules also move randomly and continuously. [2]

The candidate loses the first mark as there is no indication why the smoke particles move: there is no mention that the collision rates on the smoke particles are unequal/unbalanced. However, the second mark is awarded for the statement that the motion of the striking air molecules is random. These are B marks so the two answers are not linked and can be awarded separately.

***Candidate B***

The kinetic theory of gases states that gas molecules are in continuous, random motion. Brownian motion shows this theory, because smoke molecules are indeed seen to move continuously and randomly through the microscope. [2]

Mark awarded for the link between *kinetic theory and the random motion of gas molecules.* The candidate does not gain the additional mark in this section as there is no explanation of how this leads to the movement of the smoke particles. Compare this with the A grade candidate.

***Candidate E***

Brownian motion showed that molecules undergo elastic collision with no loss of energy by showing that invisible air molecules kept colliding with smoke particles at such a rate that bright sparks were visible. It also showed that the molecules have no forces between them. [2]

No marks gained in this section as the candidate needs to explain why the smoke particles move: unbalanced forces or unequal collision rates. Compare with the grade A and B candidates.

**(c)** Smoke from a poorly maintained engine contains large particles of soot.
Suggest why the Brownian motion of such large particles is undetectable.

***Candidate A***

The large particles of soot is being hit by air molecules in all directions. Therefore the resultant force is zero and the large particle does not move. [2]

Full marks are again awarded for the two statements that *the soot is hit by air molecules in all directions so the resultant force is zero* and so the particles do not move. Just a statement that the resultant force is zero would not be sufficient for the first mark as the statement needs justifying.

***Candidate B***

Brownian motion is applicable only for microscopic molecules like smoke particles. However, particles of soot are very large, so that their motion is barely visible. [2]

No marks awarded for this section because, although the candidate talks about *large* particles (given in the question), there is no explanation as to why this is important in averaging out forces on the smoke particles to zero.

***Candidate E***

This is so since large particles do not have a ~~negt~~ negligible volume and have forces of attraction in between them. Hence they would not be able to undergo elastic collision with air molecules. [2]

No marks for this section. Again the candidate talks about large particles – see the grade B candidate. The candidate then makes two incorrect statements showing a very poor understanding of the physics involved in Brownian Motion.

# Question 6

## General comments

**Candidate A**

The candidate in answering this question shows a very clear understanding of the physics involved in the two experiments required. There are two minor omissions which prevent the answer gaining full marks.

**Candidate B**

The candidate shows a good understanding of the basic physics of diffraction in answers to the first two parts of the question but is unable to extend this to the diffraction of longitudinal waves.

**Candidate E**

The candidate has a basic understanding of diffraction and the diagram in **(b)** gives further confirmation of this fact. However, the candidate has only a vague idea of the experimental set-up to be used.

## Specific comments

**(a) Explain what is meant by the *diffraction* of a wave.**

***Candidate A***

The diffraction of a wave ~~occurs~~ is the bending of the wave when it passes round obstacles or through apertures whose sizes are comparable to the wavelength of that wave. [2]

Full marks for this section as the candidate states that diffraction occurs when a *wave* incident on an *obstacle bends*.

***Candidate B***

Diffraction is the bending of waves round the edges as they pass through a small gap [2]

Full marks for this section: the answer contains all the points as indicated in the grade A candidate's answer.

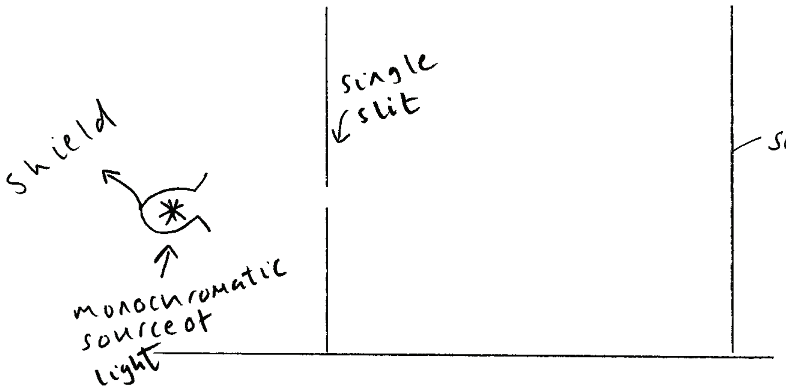
***Candidate E***

Diffraction of wave is the spreading of ~~wave~~ wave round an obstacle or an object. [2]

Full marks for this section – see grade A and B candidates.

**(b) (i)** Outline briefly an experiment that may be used to demonstrate diffraction of a transverse wave.

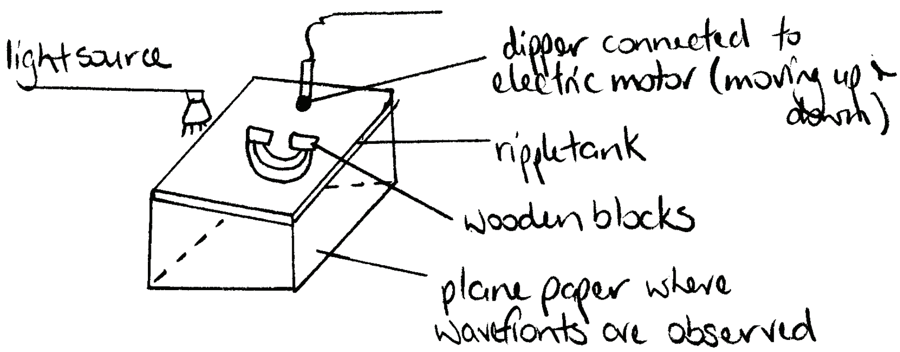
***Candidate A***




light passes through the single slit and diffracts.
The diffraction pattern is observed on the screen as a
series of alternate dark and bright fringes with the brightest fringe at the centre of the pattern. [3]

Three marks for this section. The candidate was awarded the first mark having been given the benefit of doubt that the diagram indicates a coherent source. The examiner would have preferred a slit after the source. The next two marks are awarded: one for the detector, *screen*, and one for what is observed, *dark and bright fringes*.

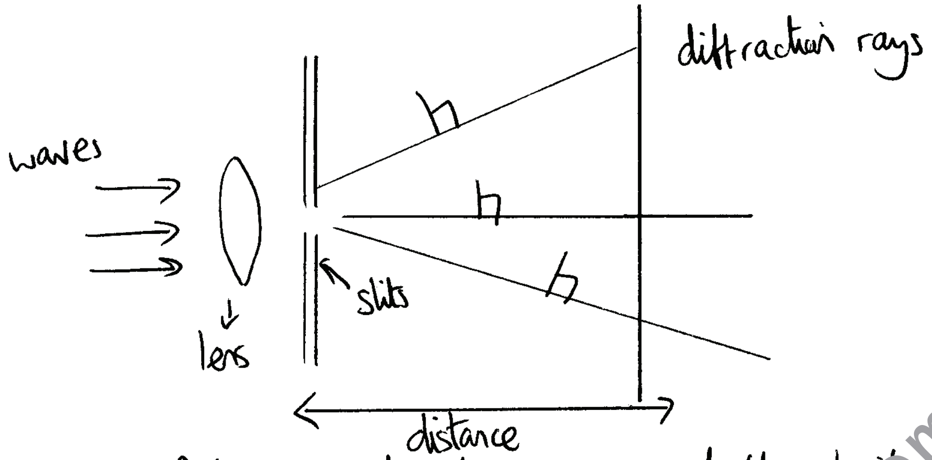
***Candidate B***




A ripple tank is set up as shown. When
wave pass the the small gap they are
diffracted [3]

This candidate uses a ripple tank as the demonstration of diffraction, a valid experimental method. This was the most common answer from candidates to this part of the question. One mark for the source, *dipper moving up and down*, one mark for the detector, *light source and plane paper*. The candidate, however, loses a mark because there is nothing to indicate what is observed. The curves drawn on the diagram are not sufficient without some explanation.

***Candidate E***

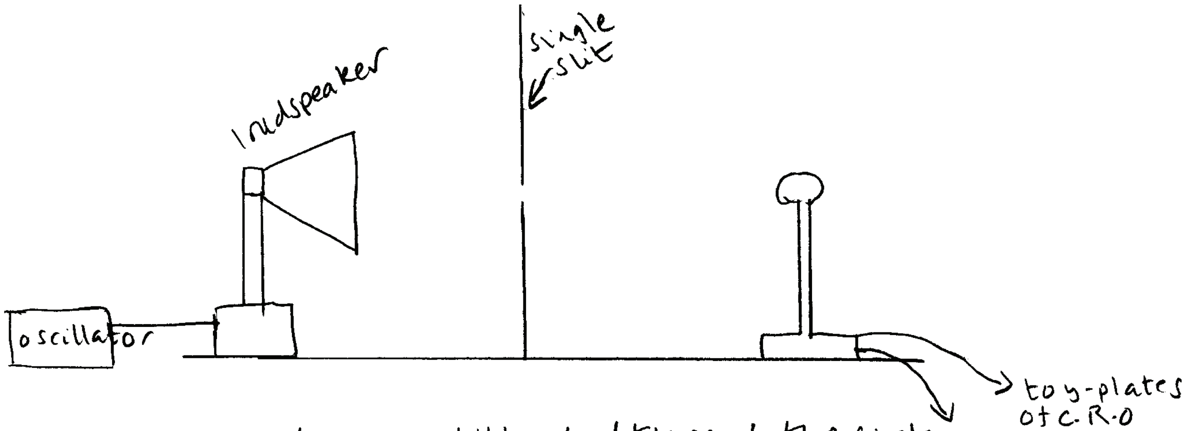



A lens is used and waves passed through it to spread through an opening. Use an apparatus to show that vibrations are propagated perpendicular to the direction of the waves. [3]

This candidate has a diagram of the correct experiment required, but the labels and the description miss all the important detail. What is the nature of the source, how is the information detected and what is observed? A few correct labels on the diagram would gain at least the last two marks as obtained by the grade B candidate with a very similar diagram.

**(ii)** Suggest how your experiment in **(i)** may be changed to demonstrate the diffraction of a longitudinal wave.

***Candidate A***




the sound wave is diffracted through the single slit and the C.R.O records pulses of waves with varying intensities. [3]

One mark out of three for this section, *loudspeaker plus slit*. However, the diagram does not label the detector as a microphone, which is not clear enough from the diagram. The statement *the CRO records pulses of waves with varying intensities* is not enough to explain what is observed. A suitable answer would require the candidate to state something on the lines of *the CRO displays a wave with an amplitude which varies as the microphone is moved*.

***Candidate B***

The dipper is made to move horizontally of the water.

[3]

No marks for this section. There is no diagram and a dipper moving horizontally would not generate longitudinal waves, unlike the answer from the grade A candidate who was able to extend the physics to a correct longitudinal experiment.

***Candidate E***

It is changed in a way that the vibrations are moved in the same direction of the waves. Another source of wave has to be used and the way to move the wave. [3]

No marks for this section as there is no attempt to provide an experimental set-up. The candidate does know the motion of the particles in longitudinal waves but there are no marks in the scheme for this information.

# Question 7

A potential divider circuit consists of two resistors of resistances *P* and *Q*, as shown in Fig. 7.1.

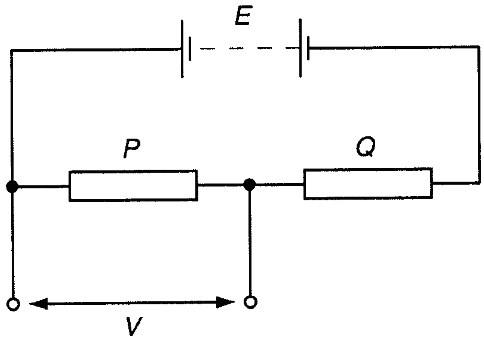



**Fig. 7.1**

The battery has e.m.f. *E* and negligible internal resistance.



## General comments

**Candidate A**

The candidate makes only two minor slips in answering this question and clearly understands the application of Ohm's law to the two circuits used.

**Candidate B**

This candidate has a clear understanding of the application of Ohm's law to the question but makes a simple error in the thermistor part of the question, which was a pity as the candidate clearly understands the physics involved.

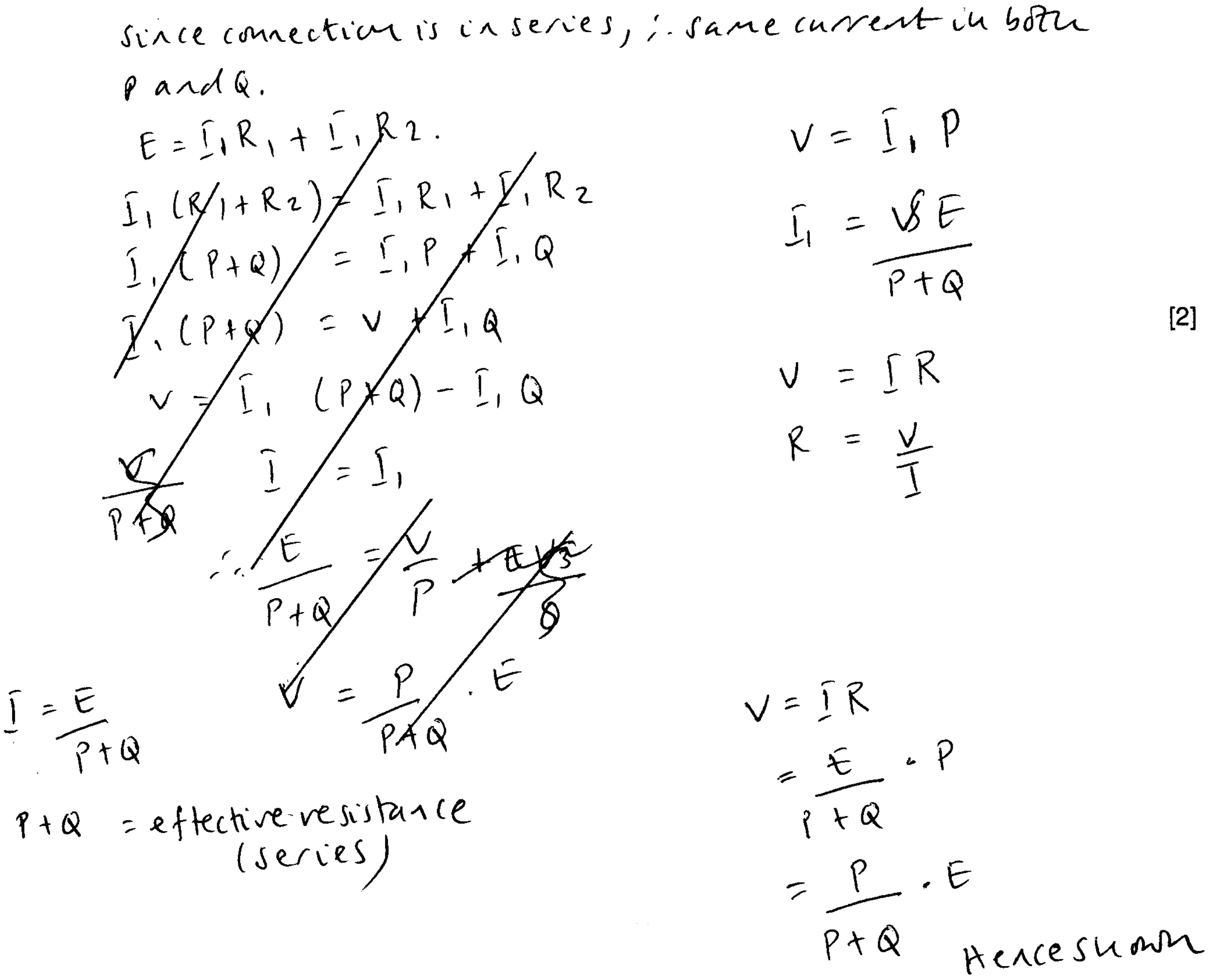
**Candidate E**

There is little to indicate that the candidate knows how to apply Ohm's law to this question, but the attempt by this candidate has some merit: the majority of poor candidates did not attempt the question at all and scored zero marks.

## Specific comments

**(a)** Deduce that the potential difference *V* across the resistor of resistance *P* is given by the expression

***Candidate A***




[2]

Full marks for this section, one for Ohm's Law, the line that $V = I_1 P$ and one mark for the current in the circuit, $I_1 = E/(P + Q)$. Benefit of doubt given to the loss of the subscript used for the current in the diagram but it is clear from the text how the candidate arrives at the answer given in the script. The marks are awarded for the method the candidate uses to arrive at the answer.

***Candidate B***

~~$V = \left(\frac{R}{R+r}\right)E$, where R is the resistance of the resistor and (R+r) is the combined resistance, and E is the EMF of battery~~

~~$\therefore V = \frac{P}{P+Q} E.$~~

[2]

$V = IR$

But $I = \frac{E}{(P+Q)}$ and $R = P$

$\therefore V = P\left(\frac{E}{(P+Q)}\right) = \frac{P}{P+Q} E.$

Full marks for this section with this candidate giving a much clearer solution than the grade A candidate.

***Candidate E***

$V = \left(\frac{R_P}{R_P R_Q}\right)E$ $\qquad E - Ir = V$

$V = \left(\frac{R_P}{R_P R_Q}\right)(V - IR_P)$

[2]

$V = \frac{R_P V - IR_P R_P}{R_P R_Q}$

$V = \frac{R_P(V - IR_P)}{R_P R_Q}$

$V = \frac{V - IR_P}{R_Q}$

$V = (V - IR_P)(R_Q)$

The candidate starts with the answer and writes it down incorrectly on the first line. No marks are awarded because it is difficult to see what the candidate is trying to prove.

**(b)** The resistances *P* and *Q* are 2000 Ω and 5000 Ω respectively.
A voltmeter is connected in parallel with the 2000 Ω resistor and a thermistor is connected in parallel with the 5000 Ω resistor, as shown in Fig. 7.2.

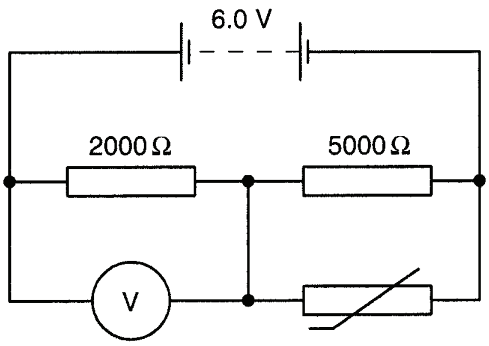



**Fig. 7.2**

The battery has e.m.f. 6.0 V. The voltmeter has infinite resistance.

**(i)** State and explain qualitatively the change in the reading of the voltmeter as the temperature of the thermistor is raised.

***Candidate A***

As temperature increases, the resistance of thermistor decreases. ~~($V \propto \frac{1}{r}$)~~ ($I \propto \frac{1}{r}$). Effective resistance of circuit decreases and hence current increases ($V \propto I$). Therefore, voltmeter reading increases. [3]

Three marks for this section with the first awarded when the candidate states that *the resistance of the thermistor decreases* as the temperature increases. The next mark is for stating that the total resistance of the parallel combination of the thermistor and 5000 Ω resistor decreases, hence increasing the voltage across the 2000 Ω resistor. The candidate answers these last two points using a valid alternative method by considering the total circuit resistance and the total current in the circuit.

***Candidate B***

When the temperature is raised, the ~~rises~~ resistance of the thermistor ~~is~~ decreases. Then, the current in the circuit also decreases, because combined resistance increases. From V=IR, the voltmeter reading decreases. [3]

The candidate gains the first mark for the change in resistance of the thermistor. The next two marks are lost as the candidate thinks that this leads to a decrease in the current in the circuit. A unfortunate slip, due to pressure in the examination?

***Candidate E***

When the temperature of the thermistor is raised, the potential difference across the circuit and the current increases resulting in a decrease in resistance. Hence increasing temperature results in a decrease in resistance. [3]

The candidate gains one mark for realising the resistance in the circuit decreases as the temperature increases, but states at one point that the current in the circuit increases because the potential difference across the circuit increases – and so clearly does not understand the concept of e.m.f.

**(ii)** The voltmeter reads 3.6V when the temperature of the thermistor is 19°C.
Calculate the resistance of the thermistor at 19°C.

***Candidate A***

∴ From Kirchoff's voltage law,

$V_{thermistor} + V_{5000\Omega} = 6 - 3.6$
$= 2.4V$

~~Effective resistance~~

Effective resistance $= \left[\frac{1}{r} + \frac{1}{5000}\right]^{-1} + 2000$

$= \frac{5000r}{5000+r} + 2000$

resistance = $1.70 \times 10^3$ Ω [4]

Current in 2000Ω $= \frac{V}{R} = \frac{3.6}{2000} = 1.8 \times 10^{-3}$

~~V thermistor~~

current in 5000Ω $= \frac{2.4}{5000} = 4.8 \times 10^{-4}$ A.

∴ Current in thermistor from Kirchoff's current law $= 1.8 \times 10^{-3} - 4.8 \times 10^{-4}$
$= 1.32 \times 10^{-3}$ A

$V = IR$

Resistance $= \frac{2.24}{1.32 \times 10^{-3}} = 1.697 \times 10^3$

$R = \frac{V}{I}$

There are two valid methods of approaching this calculation. The first method is to calculate the total current in the circuit using the voltmeter reading and then calculate how the current is split between the two parallel components. The candidate uses this method and correctly calculates the current in the circuit, 1.8 mA and the current in the 5000 Ω resistor, 0.48 mA. The candidate then makes an unfortunate substitution error in the final calculation carrying forward 2.24 as the subtraction of 6 – 3.4 for the voltage across the 5000 Ω resistor and so loses the final answer mark. The other method is to calculate the total resistance of the parallel combination, 1.33 kΩ, and then use the equation for the resistance of a parallel combination to calculate the resistance across the thermistor.

***Candidate B***

Let resistance of thermister be R.

$$V = \frac{2000}{2000 + \left(\frac{1}{5000} + \frac{1}{R}\right)^{-1}} \times 6.0$$

$$3.6 = \frac{2000}{2000 + \left(\frac{5000R}{R+5000}\right)} \times 6.0$$

~~1818.2~~

resistance = ~~1.82~~ 1800 Ω [4]

$$0.6 = \frac{2000}{2000 + \left(\frac{5000R}{R+5000}\right)}$$

$$2000 + \left(\frac{5000R}{R+5000}\right) = 3333.3$$

$$\frac{5000R}{R+5000} = 1333.3$$

$$5000R = 1333.3R + 6666.7$$

$$3666.7R = 6666.7$$

$$R = \frac{6666.7}{3666.7} = ~~1.82~~\ 1818.2$$

Full marks gained in this section with a very clear solution and an answer correctly given to two decimal places.

***Candidate E***

~~R =~~

~~$V = \frac{RV}{(R_1R_2)}$~~

~~$\frac{V}{6} = \frac{3.6R\ 6(2000)}{(2000)(5000)}$~~

=

$E - Ir = V$

$6 - \left(\frac{6}{7000}\right)r = 3.6$

$r = 2800$

resistance = 2800 Ω Ω [4]

$V = 6\,V$

$R = 7000\,\Omega$

$I = \frac{V}{R} = \frac{6}{7000}$

No marks gained. Again the candidate does not understand circuit theory as demonstrated by the addition of the 5000 Ω and 2000 Ω resistances in the second line of the calculation.

## Question 1

In this experiment you will observe the motion of two simple pendulums, and measure the interval between successive times at which the pendulums are moving together.
You will investigate how this time interval is affected when the length of one of the pendulums is changed.

**(a)** Set up two simple pendulums side by side as shown in Fig. 1.1, with each string clamped between two wooden blocks.

Set the length of pendulum A to about 0.65 m.

Pendulum A should be left at its set length throughout the experiment.

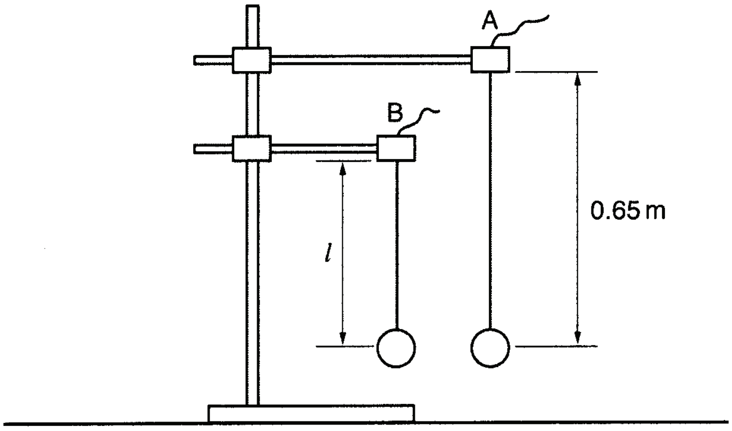



**Fig. 1.1**

**(b)** Adjust pendulum B so that its length *l* is about 0.5 m.

Measure and record the value of *l*.

**(c)** Set both pendulums into motion with small oscillations.

Start the stopwatch when the two pendulums are lined up as shown in Fig. 1.2 **and** are moving in the same direction.

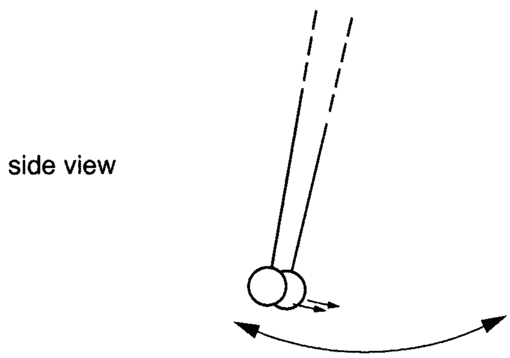



**Fig. 1.2**

Determine the time *t* that elapses before the next occasion when the two pendulums are lined up **and** moving in the same direction.

## General comments

**Candidate A** achieves a very high mark as a result of setting out the table mindful of units, consistency of raw readings, range of readings taken and also aware of the number of significant figures needed in calculated quantities. The graph is also set out to a high standard with points plotted correctly and read off accurately in order to calculate the gradient and consequently to work out *p* and *q* successfully. The highest standard is achieved despite the poor quality of some of the results perhaps owing to exam pressure.

**Candidate B** achieves a high mark owing to their ability to set out the table clearly, taking account of consistency and repeats over a suitable range of raw readings. They can achieve a higher grade by paying close attention to all column headings having appropriate units and significant figures in calculated quantities being consistent with the raw readings. The graph plots and line of best fit are drawn to a high standard, but to achieve a higher standard the candidate can check the labelling of axes and use a larger triangle to work out the gradient.

**Candidate E** is able to take raw readings, repeating them over a suitable range, and is able to set out a graph to determine the *y*-intercept successfully. To achieve a higher standard, the candidate can ensure that all column headings have an appropriate unit, raw readings are taken to the same consistency, draw a thinner line of best fit on the graph and use a larger triangle in determining the gradient.

## Specific comments

**(d)** Change $l$ and repeat **(c)** until you have six sets of values for $l$ and $t$.

$l$ should be from about 0.3 m to about 0.6 m. Include values of $\frac{1}{t}$ and $\frac{1}{\sqrt{l}}$ in your table of results.

***Candidate A***

| $l$ / m | $t_1$ / s | $t_2$ / s | $t$ / s | $1/t$ / $s^{-1}$ | $1/\sqrt{l}$ / $m^{-1/2}$ |
|---|---|---|---|---|---|
| 0.300 | 3.6 | 3.4 | 3.5 | 0.29 | 1.83 |
| 0.350 | 4.8 | 4.9 | 4.9 | 0.20 | 1.69 |
| 0.400 | 5.5 | 5.7 | 5.6 | 0.18 | 1.58 |
| 0.450 | 7.9 | 7.7 | 7.8 | 0.13 | 1.49 |
| 0.500 | 10.6 | 10.7 | 10.7 | 0.0935 | 1.41 |
| 0.560 | 19.2 | 18.6 | 18.9 | 0.0529 | 1.34 |

t : time when the 2 pendulums are lined up and moving in same direction. $t = \frac{t_1 + t_2}{2}$.

This candidate presents their results in an exemplary way. There are six sets of raw lengths (over a suitable range) and repeated time readings. Column headings are written correctly throughout including the difficult column heading of $1/\sqrt{l}$ / $m^{-1/2}$.

The number of decimal places in the time readings is consistent for each raw value of time. Each quantity of $1/t$ and $1/\sqrt{l}$ is calculated correctly. What makes this table of a high standard is that the candidate recognises the need to keep the number of significant figures in each of the calculated $1/t$ quantity the same as that in the raw values of time $t_1$ and $t_2$ from which $1/t$ has been derived. Notice $t_1 = 7.9$, $t_2 = 7.7$, $1/t = 0.13$, whilst $t_1 = 10.6$, $t_2 = 10.7$, $1/t = 0.0935$. Since $t_1$ and $t_2$ are read to three significant figures then $1/t$ is calculated and written to the same number of significant figures (*0.09346* would also have been acceptable as one more significant figure in the calculated quantity compared with the raw data is acceptable). This candidate has achieved the highest grade because there is a consistency across each row despite the fact that the number of significant figures in the calculated of $1/t$ varies down the column. There is a common misconception that the number of significant figures in the calculated quantity has to be consistent throughout the column when in actual fact the number of significant figures in the calculated quantity has to relate back to the raw data.

***Candidate B***

Table of value of time (t) against length of string (l)

| l(m) ±0,001 | Readings of time interval $t_1$ (s) | $t_2$ (s) | $t_3$ (s) | t (s) | 1/t | 1/√l |
|---|---|---|---|---|---|---|
| 0,35 | 5.22 | 5,13 | 5,01 | 5.12 | 0,20 | 1,70 |
| 0,40 | 7,12 | 7,15 | 7,10 | 7,08 | 0,14 | 1,58 |
| 0,45 | 8,53 | 8,59 | 8,62 | 8,58 | 0,12 | 1,49 |
| 0,50 | 13,16 | 13,23 | 13,19 | 13.19 | 0,07 | 1,41 |
| 0,55 | 18,72 | 18,90 | 18,85 | 18.82 | 0,05 | 1,35 |
| 0,60 | 32,38 | 32,47 | 32,30 | 32,38 | 0,03 | 1,29 |
| | | | | Centroid | 0,10 | 1,47 |

This candidate gains marks for setting out the table with a suitable range of raw readings of length and repeated readings of time all written to the same number of decimal places. Where this candidate loses out from gaining the highest grade is the failure to recognise the correct unit for the column heading of *1/t* and $1/\sqrt{l}$ as well as not writing the calculated quantity *1/t* to the same number of significant figures as the raw readings of $t_1$ and $t_2$. In particular look at the sixth row where $t_1 = 32.38$, $t_2 = 32.47$, $t_3 = 32.30$ and $1/t = 0.03$ is written to one significant figure when four or five would be acceptable (i.e. $1/t = 0.03088$ or $0.030880$).

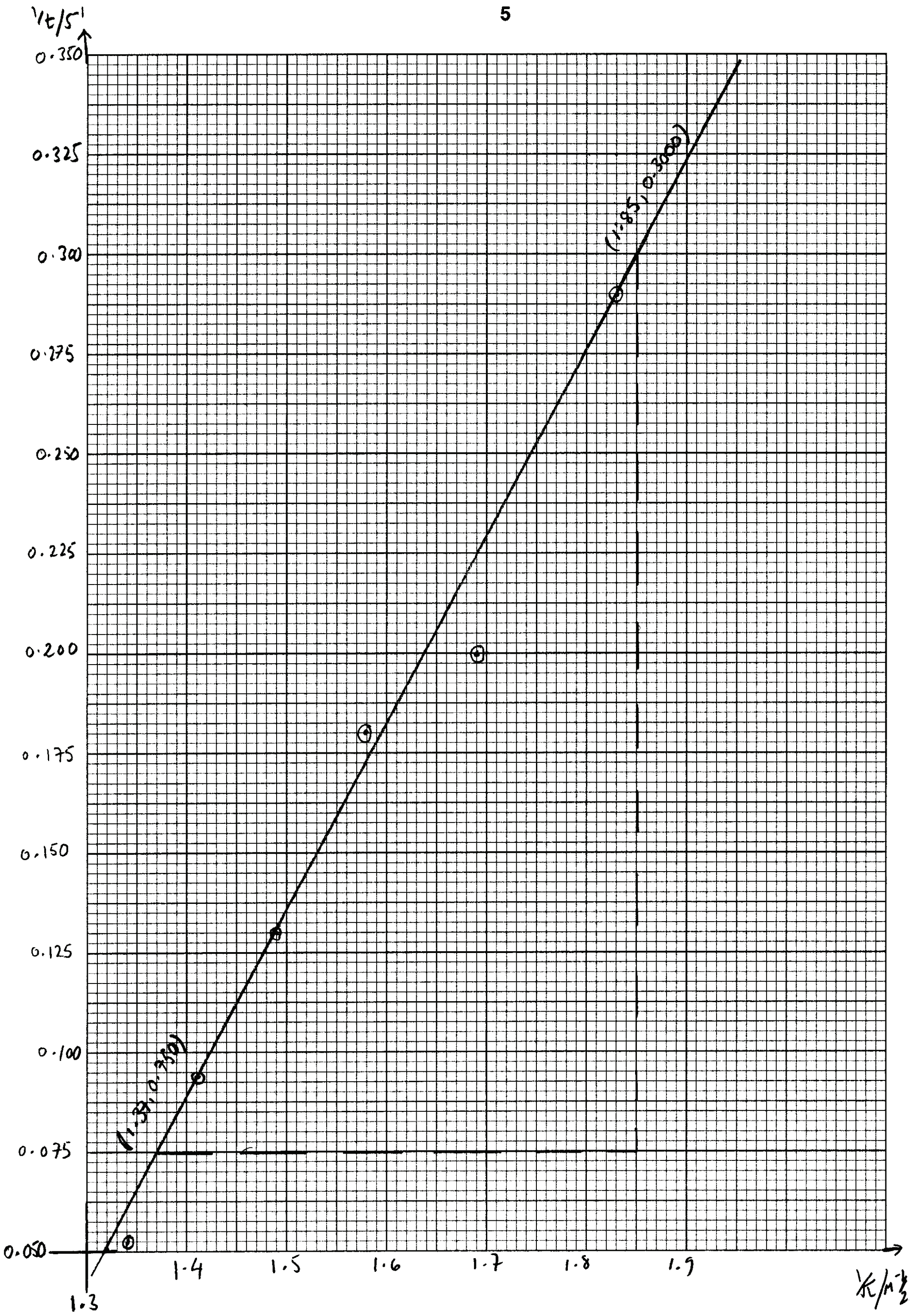
***Candidate E***

| L/M | $t_1$/s | $t_2$/s | <t>/s | 1/t /s | 1/√L /M |
|---|---|---|---|---|---|
| 0.3 | 3.22 | 3.37 | 3.3 | 0.303 | 1.8 |
| 0.4 | 6.66 | 6.68 | 6.67 | 0.15 | 1.6 |
| 0.45 | 8.71 | 8.74 | 8.7 | 0.114 | 1.5 |
| 0.5 | 11.56 | 11.58 | 11.57 | 0.086 | 1.4 |
| 0.55 | 19.53 | 19.58 | 19.6 | 0.05 | 1.3 |
| 0.6 | 36.56 | 36.6 | 36.6 | 0.027 | 1.2 |

This candidate gains a mark for taking and recording six sets of results for length over a suitable range and repeated values of time. The candidate's response fails to gain credit for the consistency mark in the time readings (see last value in $t_2$ column (*36.6*) whereas all the other values are to 2 decimal places). Also the candidate fails to recognize the correct unit of $1/\sqrt{l}$. The number of significant figures in the calculated quantity does not follow on from the number of significant figures in the raw values of $t_1$ and $t_2$ (see $t_1 = 19.53$, $t_2 = 19.58$, $1/t = 0.05$ when *1/t* should be written as *0.5114* or *0.51138*). The value of $1/\sqrt{l} = 1.2$ calculated from $l = 0.60$ m is recorded incorrectly owing to a rounding error ($1/\sqrt{l} = 1.29$ or $1.3$). This is a common error.

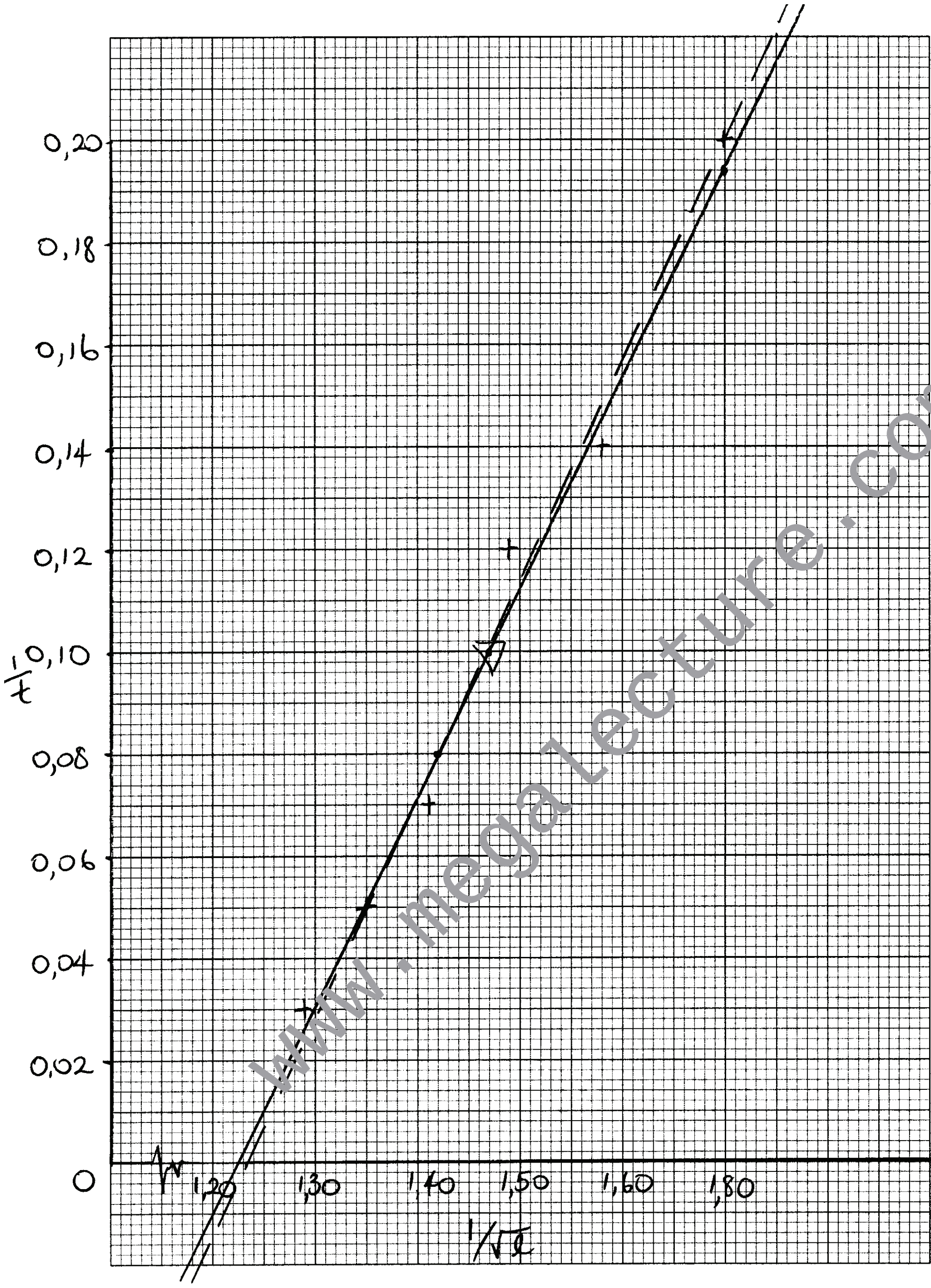
**(e)** Plot a graph of $\frac{1}{t}$ on the $y$-axis against $\frac{1}{\sqrt{l}}$ on the $x$-axis and draw the line of best fit.

***Candidate A***



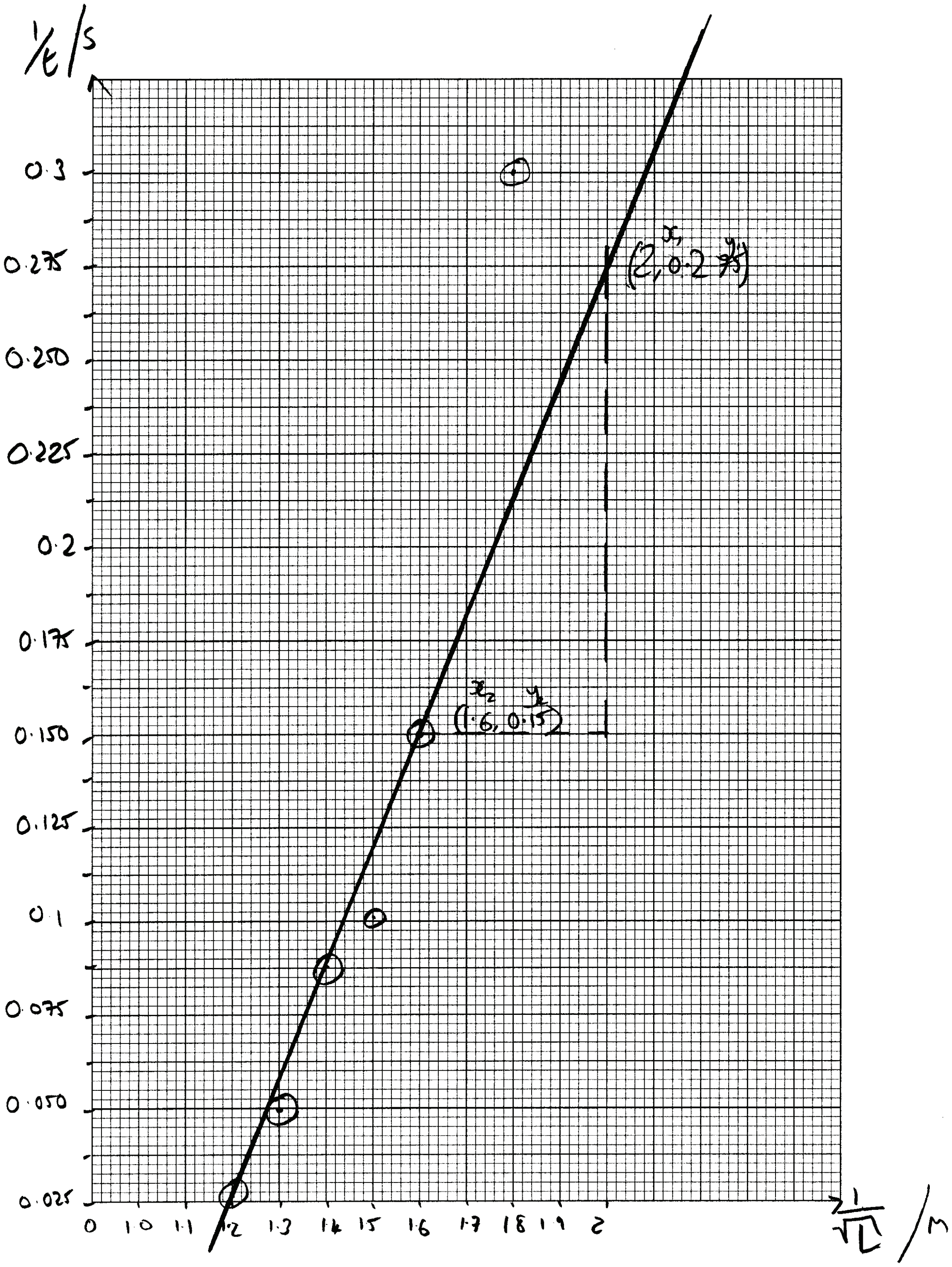

This candidate sets out the graph with correctly labelled and numbered axes even though the origin is false. The plots were plotted to within the nearest half a small square and the line of best fit drawn appropriately. One of the plots (*1.69, 0.200*) was far away from the line of best fit and so this candidate fails to gain the quality mark.

***Candidate B***




The candidate sets out a graph with axes labelled appropriately, plots plotted to within half a small square and the line of best fit drawn appropriately. However the candidate fails to achieve the highest grade owing to missing out *1.70* along the y-axis leading to a scale error.

***Candidate E***




The axes drawn are labelled and numbered appropriately. One plot (*1.8, 0.303*) was incorrectly plotted which is a common error as the *0.003* part of *0.303* was ignored and on the graph grid this amounts to one small square further up the scale. The line also failed to gain credit as it is drawn too thick. Use of a sharpened pencil will ensure the candidate gains credit.

**(f)** Determine the gradient and *y*-intercept of this line.

***Candidate A***

using (1.37, 0.0750) and (1.85, 0.3000)

$$\text{gradient} = \frac{0.3000 - 0.0750}{1.85 - 1.37} = 0.46875 \approx 0.469 \text{ (to 3 s.f.)}$$

using (0, y) and (1.37, 0.0750)

$$\text{gradient} = \frac{0.0750 - y}{1.37 - 0}$$

$$\therefore \frac{0.0750 - y}{1.37} = 0.46875$$

$$y = -0.56719$$
$$\approx -0.567 \text{ (to 3 s.f.)}$$

gradient = 0.469

*y*-intercept = −0.567

The read-offs and the calculation for determining the gradient are carried out correctly. The *y*-intercept can not be read from the graph directly so the candidate recognises the need to substitute correctly into $y = mx + c$. Common errors are that candidates will either read off the *y*-axis incorrectly when there is a false origin or rearrange $y = mx + c$ incorrectly ($y/mx = c$ instead of $y - mx = c$), or failing to read off plots correctly to within half a small square.

***Candidate B***

$$\text{Gradient} = \frac{y^1 - y^2}{x^1 - x^2}$$

$$= \frac{0{,}08 - 0{,}194}{1{,}42 - 1{,}70}$$

$$= 0{,}41$$

using (1,42 ; 0,08) + (1,70 ; 0,194)

gradient = 0,41

*y*-intercept = − 0,50

$y = mx + c$.
using centroid values

$$0{,}10 = 0{,}41(1{,}47) + c$$
$$0{,}10 - (0{,}41)1{,}47 = c$$
$$c = -0{,}50$$

The candidate reads off values for the gradient calculation correctly. However, the read-offs are from a triangle whose hypotenuse is less than half the length of the line drawn. This is a common error and fails to gain credit.

***Candidate E***

$$M = \frac{-0.125}{(1.6-2)} = 0.3$$

$$y = mx + c$$

$$0.15 = 0.3(1.6) + c$$

$$= -0.35$$

gradient = 0.3

*y*-intercept = −0.35

The candidate worked out the *y*-intercept correctly. However, the triangle used for working out the gradient was too small, failing to gain credit. A triangle drawn with a hypotenuse either equal to half of the line or greater will ensure that the candidate gains credit.

**(g)** The equation relating $t$ and $l$ is

$$\frac{1}{t} = \frac{p}{\sqrt{l}} - \frac{p}{q}$$

where $p$ and $q$ are constants.

Use your answer from **(f)** to determine a value for $p$.

**(h)** Use your answers from **(f)** and **(g)** to determine a value for $q$.

***Candidate A***

$y = mx + c$

$1/t = p\frac{1}{\sqrt{l}} + c$

$m = p$

$c = -p/q$

$p$ = gradient of line

$= 0.469 \leftarrow$ (to 3 s.f)

$p =$ 0.469 $\text{m}^{½}\text{s}^{-1}$

$-p/q$ = y-intercept

$\therefore -p/q = -0.567$

$p/q = 0.567$

$\frac{0.469}{q} = 0.567$

$q = 0.827$ (to 3 s.f)

$q =$ 0.827 $\text{m}^{½}$

This candidate recognises that $p$ = *gradient* and $-p/q$ = *intercept* and rearranges to give an appropriate value for $p$ and $q$. A common error in this particular part of the question is that candidates forget the negative sign.

***Candidate B***

$$\frac{1}{t} = \frac{p}{\sqrt{l}} - \frac{p}{q} \equiv y = mx + c.$$

$$\frac{1}{t} = y \,;\; mx = \frac{p}{\sqrt{l}} \,;\; -\frac{p}{q} = c$$

$$\therefore m = p$$

$$p = 0{,}41 \rightarrow$$

$p =$ 0, 41. $m^{1/2}s^{-1}$

$$\frac{1}{t} = \frac{p}{\sqrt{l}} - \frac{p}{q}$$

$$y = \frac{1}{t}$$

$$m = p$$

$$x = \frac{1}{\sqrt{l}}$$

$$c = -\frac{p}{q}$$

$$q = -\frac{p}{c}$$

$$q = \frac{-0{,}41}{-0{,}50}$$

$$= 0{,}82 \rightarrow$$

$q =$ 0,82 $m^{1/2}$

The candidate gains marks for recognizing *p* = *m* and –*p*/*q* = *intercept* and rearranges to get suitable values for *p* and *q*.

***Candidate E***

$$\frac{1}{t} = \frac{p}{\sqrt{L}} - \frac{p}{q}$$

$$y = Mx + C$$

p=M
p=gradient

$$\frac{1}{\sqrt{L}} \,(p) \;\; \| \;\; Mx$$

*p* = 0.3 $m^{1/2}s^{-1}$

$$\frac{1}{t} = \frac{0.3}{\sqrt{L}} - \frac{0.3}{q}$$

$$\frac{-p}{q} = C$$

$$-\frac{0.3}{q} = -0.35$$

$q =$

*q* = 0.9 $m^{1/2}$



The candidate recognises that *p* = *gradient* and –*p*/*q* = *intercept* and gains some credit. However, *p* was out of range to gain full credit. The values are out of range not owing to the size of the triangle used to determine the gradient (the read-offs were given correctly), but instead to the poor quality of results judged by looking at the scatter of the points about the line of best fit. This wide scatter is attributable to the number of significant figures taken for *1/t* and $1/\sqrt{l}$ in the table. The error in the table early on often leads to marks lost at the graphical and analysis stage, and is a common error.

# Question 2

## General comments

**Candidate A** achieves a very high standard by recording all results mindful of the need to repeat their results and write them to an appropriate degree of accuracy. They are able to calculate the percentage uncertainty successfully, estimate the length of wire in a single turn, the resistance, the resistance per meter and a proportionality constant in order to verify the relationship between the resistance and the number of turns. The high standard is achieved despite the fact that not all the limitations and solutions relate directly to the experiment.

**Candidate B** achieved a high standard in taking down all the results and successfully calculating appropriate values of percentage uncertainty, length of wire in a single turn, resistance, resistance per meter and a proportionality constant. To gain a higher standard the candidate can repeat their raw readings of the diameter and make their limitations and solutions more specific to improving the experiment in question as opposed to changing the experiment.

**Candidate E** was competent in taking down the electrical results and working out the resistance and the resistance per meter. To achieve a higher grade, this candidate can measure the raw reading of the diameter of the tube to the appropriate number of decimal places, repeat their raw readings of the diameter, set up the circuit the right way round, work out a proportionality constant to verify a relationship between the resistance and the number of turns, and describe clearly the limitations and improvements specific to this experiment.

## Specific comments

***Candidate A***

In this experiment you will investigate the resistance of a wire coil.

**(a)** You have been provided with a coil as shown in Fig. 2.1.

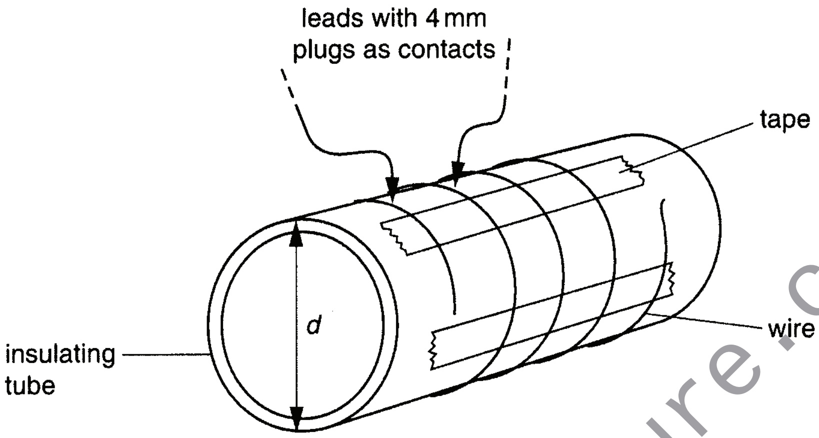



**Fig. 2.1**

**(i)** Measure and record the diameter *d* of the insulating tube.

| Diameter of the insulating tube/m | | |
|---|---|---|
| 1 | 2 | average |
| 0.042 | 0.042 | 0.042 |

$d =$ 0.042 m



**(ii)** Estimate the percentage uncertainty in your value for *d*.

percentage uncertainty in d $= \frac{\Delta d}{d} \times 100$

$= \frac{0.001}{0.042} \times 100 = 2.38\%$

percentage uncertainty = 2.38%

**(iii)** Use your value from **(i)** to estimate the length *x* of wire in a single turn.

$x = 2\pi r$

$= 2\pi(\frac{d}{2})$

$= \pi \times 0.042$

$= 0.132$ m

$x =$ 0.132 m

This high grade candidate understands the need to repeat their raw readings of the diameter and measures to the nearest mm. They are able to estimate the length of a single turn using $2\pi r$ in their calculation.

**(b)** Set up the circuit as shown in Fig. 2.2, and hold the contacts against two positions on the coil.

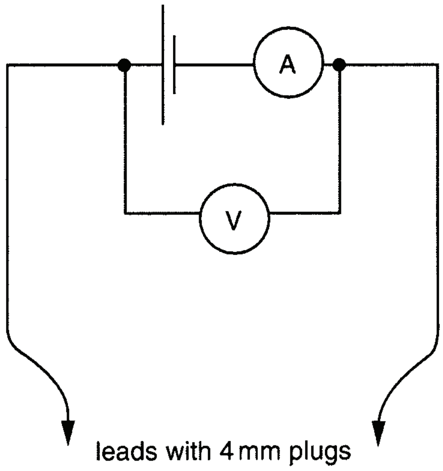



**Fig. 2.2**

**(c)** **(i)** Measure and record the number $n$ of turns between the contacts, voltage $V$ and current $I$.

$n$ = 1

$V$ = 1.0 V

$I$ = 0.26 A

**(ii)** Determine the resistance $R$ between the contacts.

$R = \frac{V}{I} = \frac{1.0V}{0.26A} = 3.8 \Omega$

$R$ = 3.8 Ω

**(iii)** The resistance per metre $\mu$ of the wire is given by

$$\mu = \frac{R}{xn}$$

Use your results to determine a value for $\mu$.

$\mu = \frac{R}{xn}$

$= \frac{3.8 \Omega}{(0.132 \times 1) m}$

$= 28.8 \Omega m^{-1}$

$\mu$ = 28.8 Ω m⁻¹

**(d)** Repeat **(c)** for a different value of *n*.

| n | V/V | | | I/A | | |
|---|---|---|---|---|---|---|
| | $V_1$ | $V_2$ | $V_{average}$ | $I_1$ | $I_2$ | $I_{average}$ |
| 3 | 1.3 | 1.3 | 1.3 | 0.12 | 0.12 | 0.12 |

$R = \frac{V}{I} = \frac{0.13V}{0.12A}$

$= 11\Omega$

$\mu = \frac{R}{xn}$

$= \frac{11\Omega}{(0.132 \times 3)m}$

$= 27.8\Omega m^{-1}$

*n* = 3

*V* = 1.3 V

*I* = 0.12 A

*R* = 11 Ω

*μ* = 27.8 Ω m⁻¹

**(e)** Explain whether your results support the idea that *R* is proportional to *n*.

$R \propto n$

$R = kn$

$k = \frac{R}{n}$

n = 1

R = 3.8 Ω

$k_1 = \frac{3.8}{1}$

= 3.8 Ω

n = 3

R = 11 Ω

$k_2 = \frac{11}{3}$

= 3.7 Ω

Percentage difference between $k_1$ and $k_2$

$= \frac{3.8 - 3.7}{3.8} \times 100$

= 2.63%

From the result of this experiment, it shows that R is proportional to n. This is because the constant k for both results are almost the same and their percentage difference is small, so R is considered to be proportional to n.

This candidate measures and records *n*, *V* and *I* to good effect and uses these results to calculate *R* and *μ* successfully. This candidate is able to go on to achieve a high standard by explaining whether there is a relationship between *R* and *n* by working out a proportionality constant first.

***Candidate B***

In this experiment you will investigate the resistance of a wire coil.

**(a)** You have been provided with a coil as shown in Fig. 2.1.

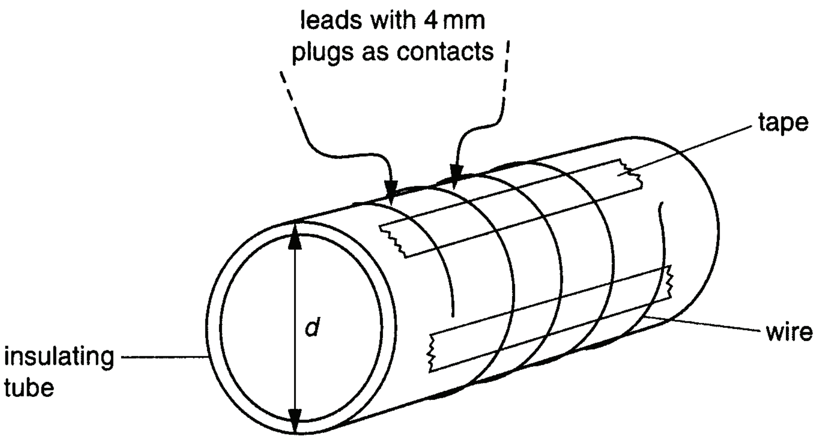



**Fig. 2.1**

**(i)** Measure and record the diameter *d* of the insulating tube.

5.6 cm = 0.056 m

*d* = 0.056 m

**(ii)** Estimate the percentage uncertainty in your value for *d*.

least count = 0.001 m $\frac{0.001}{0.056} \times 100$

percentage uncertainty = 1.8%

**(iii)** Use your value from **(i)** to estimate the length *x* of wire in a single turn.

d = 0.056

circumference = πD

*x* = 0.176 m

**(b)** Set up the circuit as shown in Fig. 2.2, and hold the contacts against two positions on the coil.

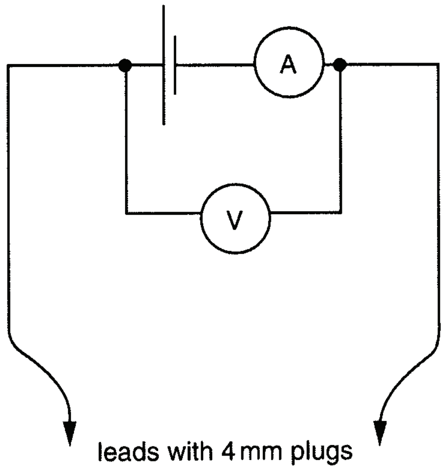



**Fig. 2.2**

**(c) (i)** Measure and record the number $n$ of turns between the contacts, voltage $V$ and current $I$.

$n$ = 4 turns

$V$ = 0·96 V

$I$ = 2·5 mA

**(ii)** Determine the resistance $R$ between the contacts.

V = IR

~~0·65 = (0~~

0·96 = (2·5 × 10⁻³)R

$R$ = 384 Ω

**(iii)** The resistance per metre $\mu$ of the wire is given by

$$\mu = \frac{R}{x\,n}$$

Use your results to determine a value for $\mu$.

$\mu = \frac{384}{0.176 \times 4}$

$\mu$ = 546

**(d)** Repeat **(c)** for a different value of *n*.

$V = IR$

$0.66 = (3.2 \times 10^{-3})R$

$R = 206.25$

$\mu = \frac{206.2}{0.176 \times 2}$

$n =$ 2

$V =$ 0.66 V

$I =$ 3.2 mA

$R =$ 206.2 Ω

$\mu =$ 586

**(e)** Explain whether your results support the idea that *R* is proportional to *n*.

$R \propto n$

$R = \mu \times n$ (k)

Constant $k = 546 \times 0.176$
$= 96$

$R \propto n$

$R = \mu \times n$ (k)

$k = 586 \times 0.176$
$= 103$

The constants of proportionality are not the same. probably due to errors and limitations in the experiment, however they fall in a very narrow range which is 96 (for experiment 1) and 103 for experiment 2 showing a proportional ratio between R and n.

This candidate achieves a high grade for taking results, calculating percentage uncertainty, circumference, *R*, *μ* and confirming a relationship between *R* and *n* using a proportionality constant. However, this candidate fails to repeat their raw results of diameter in **(a)(i)**.

***Candidate E***

This candidate has gained credit for taking measurements of $n$, $V$ and $I$ and for working out $R$ and $\mu$ correctly. However this candidate falls short of higher marks owing to the following points:

In this experiment you will investigate the resistance of a wire coil.

**(a)** You have been provided with a coil as shown in Fig. 2.1.

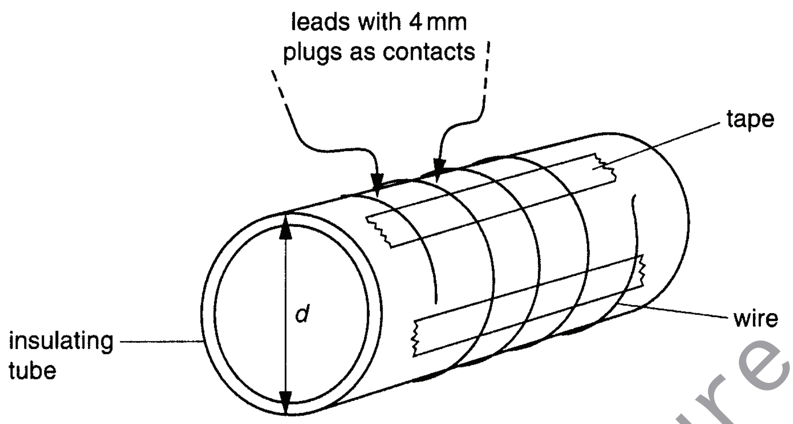



**Fig. 2.1**

**(i)** Measure and record the diameter $d$ of the insulating tube.

$d$ = 0.04 m

**(ii)** Estimate the percentage uncertainty in your value for $d$.

Same for all.

$\frac{0.001}{0.04} \times 100$.

percentage uncertainty = 2.5%

**(iii)** Use your value from **(i)** to estimate the length $x$ of wire in a single turn.

$x$ = 0.04 m

The candidate fails to measure the diameter to a precision greater than a centimetre in **(i)** $d$ = *0.04* m. The candidate is provided with a ruler with a millimetre scale so should be able to write their readings to the nearest millimetre e.g. $d$ = *4.0* cm or $d$ = *0.040* m. The candidate fails to repeat their raw readings of $d$. $d$ is expected to be repeated in different directions as the tube is not assumed to be a perfect cylinder. This candidate then goes on to calculate $x$ incorrectly in **(iii)**, $x$ = *0.04* which is the same as $d$ and no calculation of $x = \pi d$ is present.

**(b)** Set up the circuit as shown in Fig. 2.2, and hold the contacts against two positions on the coil.

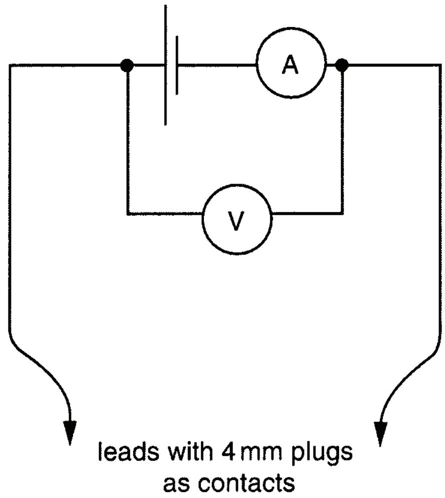



**Fig. 2.2**

**(c) (i)** Measure and record the number $n$ of turns between the contacts, voltage $V$ and current $I$.

$n$ = 4

$V$ = −1.46

$I$ = −0.09

**(ii)** Determine the resistance $R$ between the contacts.

$V = IR$

$R = \frac{V}{I} = \frac{-1.46}{-0.09} =$

$R$ = 16.2

**(iii)** The resistance per metre $\mu$ of the wire is given by

$$\mu = \frac{R}{xn}$$

Use your results to determine a value for $\mu$.

$\mu = \frac{16.2}{0.04 \times 4}$

$\mu$ = 101.25

**(d)** Repeat **(c)** for a different value of $n$.

$R = \frac{1.48}{0.07} = 21.1$

$\mu = \frac{21.1}{0.04 \times 5} = 33.6$

$n =$ 5

$V =$ −1.48

$I =$ −0.07

$R =$ 21.1

$\mu =$ ~~[illegible]~~ 105.5

**(e)** Explain whether your results support the idea that $R$ is proportional to $n$.

Comparing results of (c) and (d), we notice that with the increase number of 'n', there is an increase in resistance. And since μ also increase proportionally, it can be stated that R ∝ n.

The candidate sets up their circuit with the battery in the opposite direction as $I$ and $V$ values are negative, so the candidate fails to gain full credit for the measurements taken. In **(e)** the candidate explains that as $n$ increases, $R$ increases, hence $\mu$ increases so $R$ is proportional to $n$. The candidate has not realised that if $R$ is proportional to $n$ then $\mu$ would in fact be constant (i.e. $\mu x = k$, the proportionality constant if $R$ is proportional to $n$) so fails to gain credit.

*Candidate A*

**(f) (i)** State four sources of error or limitations of the procedure in this experiment.

1. Two readings ~~are~~ taken only are not enough to draw a valid conclusion.
2. The length of wire per turn on the insulating tube may vary and is not consistent for every turn.
3. Difficulty in holding the contacts against the coil causing the ammeter and voltmeter reading fluctuate.
4. Difficulty in measuring the diameter of the insulating tube by using meter rule/ruler.

**(ii)** Suggest four improvements that could be made to the experiment. You may suggest the use of other apparatus or different procedures.

1. Take more readings on the number of turns, n and Resistance, R and plot a graph.
2. Use a thick wire to wind on the insulating tube so that its length per turn will be more consistent.
3. Replace the insulating tube and wire with a movable resistor with varying length, the result is more precise.
4. Use vernier calliper to measure the diameter of the insulating tube so that its reading will be more accurate.

This candidate achieves a high standard by stating in detail three sources of error for this particular experiment: two readings are not enough to draw a valid conclusion; length of wire per turn on insulating tube may vary and difficulty in holding contacts against the coil causing the ammeter and voltmeter to fluctuate.

In describing solutions the candidate is credited by suggesting to 'take more readings on the number of turns *n* and resistance *R* and plot a graph' and 'use a vernier calliper to measure the diameter'.

***Candidate B***

**(f) (i)** State four sources of error or limitations of the procedure in this experiment.

1. The number of readings to determine the proportionality ratio were not enough.
2. Due to an unstable coil, the value for current and voltage kept fluctuating.
3. The coil had a limited number of turns, therefore only a limited number of readings can be taken.
4. The diameter could not be measured accurately due to the unstable paper.

**(ii)** Suggest four improvements that could be made to the experiment. You may suggest the use of other apparatus or different procedures.

1. A bigger coil with more turns can be used
2. A wider range of readings can be taken for voltage and current and hence a graph of resistance against n can be drawn to determine proportionality
3. Different coils can be used with different thicknesses.
4.



Credit was awarded for 'number of readings to determine the proportionality were not enough' and 'the values for $I$ and $V$ kept fluctuating'. The candidate, however, loses credit for not explaining the errors or limitations and solutions in enough detail. For instance, credit was not awarded for 'the diameter could not be measured accurately due to unstable paper'. If the candidate refers instead to the diameter being non-circular or the need to take repeats in different directions then credit can be awarded. Credit was also not awarded for 'the coil had a limited number of turns therefore only a limited number of readings could be taken' which relates back to their first credited source of error and so cannot be credited again.

In suggesting improvements, the candidate is awarded credit for 'a wider range of readings can be taken for $V$ and $I$ and hence a graph of $R$ verses $n$ can be drawn.' The candidate's suggestion of a 'bigger coil' and use 'different thicknesses' changes the nature of the experiment and both solutions do not describe how these are improvements to the current experiment so fail to gain credit.

Often candidates lose out by suggesting changing the nature of the experiment. Instead they should be specific to the experiment and state how to improve it.

***Candidate E***

**(f) (i)** State four sources of error or limitations of the procedure in this experiment.

1. The estimated value of x doesn't give exact length of wire in the coil.
2. Delay in reading value of voltmeter would change value of experiment.
3. Delay in reading value of ammeter would also change value at determination of readings.
4. Different wires of different resistance used could give wrong values

**(ii)** Suggest four improvements that could be made to the experiment. You may suggest the use of other apparatus or different procedures.

1. A better source of energy could be used.
2. The coil should have more wires so that larger range of values could be taken.
3. A crocodile clip could be used to clip the wire of the coil easily.
4. A vernier calliper could be used to give an exact value of d.

This candidate fails to gain credit for most of this section as their sources of error and solutions lack clarity and detail specific to this particular experiment. For example, the candidate states 'the estimated value of *x* doesn't give exact length of wire in the coil'. This statement is true but does not describe the source of error. The candidate needs to say that the coils are not circular i.e. they are helical or *x* is different to $\pi d$ to gain the mark.

Another example is that the candidate states 'delay in reading value of voltmeter would change (the) value of (the) experiment'. In order to gain credit, the candidate needs to say that the readings are fluctuating either because the experiment is difficult to hold or that there is contact resistance. The other sources of error do not relate specifically to this particular experiment.

Looking at the stated solutions, the candidate does gain credit for stating to use a 'vernier calliper' to give a more accurate value of *d*. However, the candidate fails to gain credit for stating that 'the coil should have more wires so that a larger range of values could be taken'. The candidate can gain more credit for stating that two readings of *n* are not enough and then for stating that more readings of *n* are required, and plot a graph of *n* against *R* (therefore more turns are needed).

# Question 2

## General comments

**Candidate A**

The correct answers to all the sections are clearly provided.

**Candidate B**

A very good set of answers with a clear understanding of the physics involved. The candidate made just two minor errors, the second of which was a common error on many scripts.

**Candidate E**

This paper is typical of a grade E answer, where the candidate has some understanding of the basic physics involved in answering the question but is unable to give much of the extra detail required.



## Specific comments

**(a)** Define *specific latent heat of fusion.*

***Candidate A***

Specific latent heat of fusion is the heat energy required to melt unit mass of solid at its melting point. [2]

Full marks awarded with *melt unit mass of solid* accepted, although the examiner would have liked to see *convert unit mass of solid to liquid. At its melting point* accepted as equivalent to *without a change in temperature*.

***Candidate B***

Specific latent heat of fusion is defined as the amount of energy needed to convert unit mass of solid to the liquid state at constant temperature [2]

Full marks for a complete definition.

***Candidate E***

It is the energy required to change 1kg of a solid into a liquid at constant temperature.

[2]

A common error with grade E candidates who do not realise definitions must be general and not specific to one set of units. One mark lost for the use of 1kg.

**(b)** Some crushed ice at 0 °C is placed in a funnel together with an electric heater, as shown in Fig. 2.1.

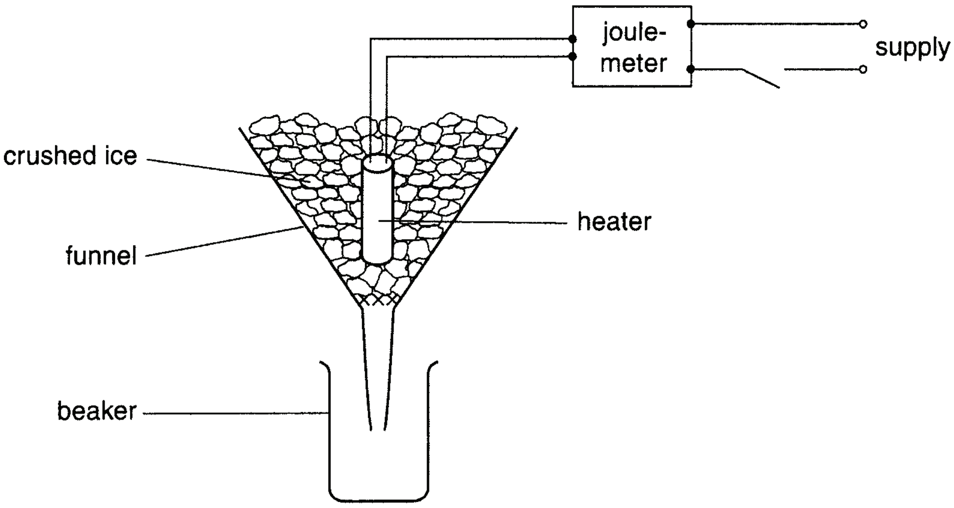



**Fig. 2.1**

The mass of water collected in the beaker in a measured interval of time is determined with the heater switched off. The mass is then found with the heater switched on. The energy supplied to the heater is also measured.
For both measurements of the mass, water is not collected until melting occurs at a constant rate.
The data shown in Fig. 2.2 are obtained.

| | mass of water / g | energy supplied to heater / J | time interval / min |
|---|---|---|---|
| heater switched off | 16.6 | 0 | 10.0 |
| heater switched on | 64.7 | 18000 | 5.0 |

**Fig. 2.2**

**(i)** State why the mass of water is determined with the heater switched off.

***Candidate A***

to calculate heat absorbed from the surrounding so that a accurate specific latent heat of fusion can be calculated. [1]

Full marks as the candidate correctly identifies the reason for collecting water when the heater is switched off.

***Candidate B***

To know if melting has occured.
[1]

No marks for this answer. For the mark to be awarded, some reference to the need to *measure the amount of heat gained from the surroundings* is required.

***Candidate E***

This is because ice absorbs heat from the surronding which causes melting.
[1]

No marks for this section. This is again a typical answer from grade E candidates who know the question has something to do with heat from the surroundings but are not specific as to how the information is to be used.

**(ii) Suggest how it can be determined that the ice is melting at a constant rate.**

***Candidate A***

when melted ice (water) drops to the beaker. this can be found by continually weighing the mass of water in the beaker until the rate of increase of mass becomes constant
[1]

Full marks as the candidate correctly identifies that it is the *rate of increase of mass* which must be constant.

***Candidate B***

The mass of water is collected at different but constant time interval is determined from which rate of melting can be calculated.
[1]

The candidate gains the mark having been given the benefit of doubt with the answer written having talked about the *mass of water collected in a constant time interval* from which the *rate can be calculated*. The candidate could have added that the rate must be constant although it is implied in the question.

***Candidate E***

The mass of water collected in a specific lapse of time is constant.
[1]

The statement *mass collected in a specific lapse of time* gains one mark. However, it is not clear from this simple statement that the measurement is repeated and resultant masses collected should be constant.

**(iii)** Calculate a value for the specific latent heat of fusion of ice.

***Candidate A***

Heat energy supplied from the heater, Q2 = 18000 J.
In 5 minutes, mass of ice melted ~~without~~ with heater switched off = 8.3g
$Q = mL$
$L = Q/M$
$= 18000/(64.7-8.3)\times10^{-3}$
$= 3.191\times10^{5}\ J\ kg^{-1}$
$= 319\ kJ\ kg^{-1}$ (3sf)

latent heat = ........319........ kJ kg$^{-1}$ [3]

Full marks for a correct calculation of the specific latent heat of fusion of ice to a suitable number of significant figures. The candidate clearly noted the difference in times for the measurement with the heater off and on.

***Candidate B***

$H = mL_v$
$1800 = (64.7-16.6)L_v$
$L_v = \frac{1800}{(64.7-16.6)\times10^{-3}}$
$= 374.2\ kJ\ kg^{-1}$
$\simeq 374\ kJ\ kg^{-1}$

latent heat = ........374........ kJ kg$^{-1}$ [3]

The candidate loses one mark making the common mistake of missing the different time intervals for the collection of water with the heater on and off, but then performs a correct calculation using the incorrect value for the mass of water collected with the heater off. Candidates are advised always to look out for such differences. This calculation requires a further two conversions since the mass of water collected is quoted in g and the heat values supplied in J. The answer required has to be given in units of kJ kg$^{-1}$ . The candidate realises this as the mass collected is written in kg in performing the calculation and there is a correct conversion to kJ in the answer.

***Candidate E***

$$Q = ml_f$$

$$l_f = \frac{Q}{m} = \frac{18000}{64.7} = 278.2$$

latent heat = 278.2 kJ $kg^{-1}$ [3]

The candidate makes three mistakes. The first two marks are lost for not taking the heat absorbed from the surroundings into account, and the final mark is lost for not realising that the values need to be converted into kJ and kg; see the grade B candidate.

# Question 5

Two deuterium ($^2_1H$) nuclei are travelling directly towards one another. When their separation is large compared with their diameters, they each have speed *v* as illustrated in Fig. 5.1.


**Fig. 5.1**

The diameter of a deuterium nucleus is $1.1 \times 10^{-14}$ m.

## General comments

**Candidate A**

A very good answer to this question with only one minor detail missing in **(a)**.

**Candidate B**

This is typical of a grade B candidate where the candidate finds the non-standard question in **(a)** difficult but can perform the routine calculation in **(b)** with little difficulty.

**Candidate E**

Many candidates providing grade E answers were unable to start **(a)** but made some attempt at the more standard section **(b)**.

## Specific comments

**(a)** **Use energy considerations to show that the initial speed *v* of the deuterium nuclei must be approximately $2.5 \times 10^6\,\mathrm{m\,s^{-1}}$ in order that they may come into contact. Explain your working.**

***Candidate A***

$$W.D = \frac{Q_1 Q_2}{4\pi \varepsilon_0 r} \qquad KE = \frac{1}{2} mv^2$$

$$WD = KE$$

$$\frac{(1.6\times10^{-19})^2}{4\pi(8.85\times10^{-12})(1.1\times10^{-14})} = \frac{1}{2}(2\times2\times1.67\times10^{-27})v^2$$

$$2.093\times10^{-14} = 3.34\times10^{-27}\,v^2$$

$$v = \sqrt{\frac{2.093\times10^{-14}}{3.3\times10^{-27}}} = 2.5\times10^6\,\mathrm{ms^{-1}}$$

[3]

The question asks candidates to explain their working, and this candidate clearly states there is a link between kinetic energy and potential energy/work done. However, this is not sufficient as it is important to state that it is the *change* in these two quantities which is linked and so the candidate loses the first mark. The rest of the calculation gains full marks.

***Candidate B***

Radius of deuterium nucleus $= 5.5\times10^{-5}$ m

$E_k = \frac{1}{2}mv^2$ density of nucleus $\frac{4}{3}\pi r^3$

$=$

[3]

There is nothing written in this section that is worthy of any marks.

***Candidate E***

$\frac{1}{2}mv^2$

Nothing mark-worthy in this section.

**(b)** For a fusion reaction to occur, the deuterium nuclei must come into contact. Assuming that deuterium behaves as an ideal gas, deduce a value for the temperature of the deuterium such that the nuclei have an r.m.s. speed equal to the speed calculated in **(a)**.

***Candidate A***

$p = \frac{1}{3}\frac{NM}{V}\langle c^2\rangle$

$pV = nRT$

$\frac{1}{3}\frac{NM}{V}\langle c^2\rangle \times V = nRT$

$\frac{1}{2}NM\langle c^2\rangle = \frac{3}{2}nRT = \frac{3}{2}NkT$

$\frac{1}{2}(2)(2\times1.67\times10^{-27})(2.5\times10^6)^2 = \frac{3}{2}(2)(1.38\times10^{-23})T$

~~$\frac{1}{2}(2)(2\times1.67\times10^{-27}) = \frac{3}{2}(2)(8.31)$~~ ~~$(1.38\times10^{-23})$~~

$2.088\times10^{-14} = 4.14\times10^{-23}T$

$\therefore T = 5.04\times10^8$ K

temperature = $5.04\times10^8$ K [4]

Full marks for this section; the candidate states the correct equations to use and performs a perfect calculation.

***Candidate B***

$E_k = \frac{3}{2}kT$

$\frac{1}{2}\times2\times1.67\times10^{-27}\times(2.5\times10^6)^2 = \frac{3}{2}\times1.38\times10^{-23}\times T$

$\Rightarrow T = 5.04\times10^8$ K

temperature = $5.0\times10^8$ K [4]

The candidate performs this routine calculation correctly, realising that the answer given in **(a)** needs to be squared. A common error was that candidates forgot to square the value given **(a)**.

***Candidate E***

$\frac{3}{2}kT$

$\frac{3}{2}kT = \frac{1}{2}mv^2$

$T = \frac{2}{6}\frac{mv^2}{k}$

$T = \frac{\frac{1}{3}\times(3\times1.6\times10^{-27})\times(2.5\times10^6)^2}{1.38\times10^{-23}}$

$T = 29\times10^8$

temperature = $29\times10^8$ K [4]

The candidate knows the equation to use, although includes a $v^2$ rather than $\langle c^2\rangle$. The candidate then makes a further two mistakes. The first is to write that deuterium has three particles in the nucleus; the second is an arithmetic error in calculating the answer. The use of $1.6\times10^{27}$ rather than $1.67\times10^{27}$ is ignored. One mark awarded.

**(c)** Comment on your answer to **(b)**.

***Candidate A***

In order for the fusion reaction to occur, extreme high temperature needs to be generated in order for both the nuclei come into contact. [1]

The candidate realises that an *extreme high temperature* is required and gains the mark, although the examiner would have preferred it to be linked to the previous answer. A common error in this part of the question.

***Candidate B***

The temperature acheived is very large during a fusion reaction. [1]

Full marks as the candidate realises that the temperature is *very large.* Again, it is not clear the candidate has made the link with the previous section.

***Candidate E***

A lot of energy is required to ~~[illegible]~~ fuse two deuterium atoms together. [1]

The candidate has some idea of the physics of the problem by talking about *a lot of energy is required* but does not relate this to temperature or the answer calculated in **(b)**.

# Question 7

## General comments

**Candidate A**

Overall an excellent answer from this candidate with just the answer to **(b)(ii)** requiring some clarification. Section **(b)(ii)** produced very poor answers from a majority of candidates.

**Candidate B**

Some very good responses to the descriptive sections, but this candidate made some simple errors in the calculation in **(c)(ii)**.

**Candidate E**

The candidate shows a very basic understanding of the photoelectric effect and the nature of photons, but is unable to relate this to atomic spectra.

## Specific comments

**(a)** **State three pieces of evidence provided by the photoelectric effect for a particulate nature of electromagnetic radiation.**

***Candidate A***

1. There is a minimum frequency (threshold frequency) at which photoelectric effect occurs. This shows that the energy is distributed in a discrete manner.

2. The photocurrent is increased by increasing the intensity of the wave, showing that more electrons are liberated when more photons are incident.

3. The ~~[illegible]~~ stopping potential cannot be increased by increasing the ~~frequency~~ intensity, but by increasing the frequency. This shows that the maximum kinetic energy of photons is independent of the intensity [3]

There are five pieces of evidence the candidate could include, and maximum marks are awarded for any three. In this case the candidate correctly identifies three out of the five possibilities.

***Candidate B***

1. No photoelectric can occur under a frequency known as the ~~thres~~ threshold frequency, $f_0$.
2. Photoelectric effect is instantaneous.

3. If the intensity of the incident photons is increased, more photoelections are emitted but they have the same maximum kinetic energy. [3]

Three correct pieces of evidence for full marks.

***Candidate E***

1. Emmision of electrons does not depend on intensity of radiation only.
2. The light incident on metal must be more than a certain threshold frequency for e.m radiation to occur.
3. E.m. radiation consists of packets of energy instead of continuous beam of energy. [3]

The candidate nearly has the first piece of evidence correct but needed to clarify the term *emission*. Does the candidate mean rate of emission or does the candidate mean the condition for the emission to take place at all? The threshold frequency mark is gained. The final example is just a statement of the particulate nature of light, not a piece of evidence for the photoelectric effect.

**(b) (i)** Briefly describe the concept of a photon.

***Candidate A***

A photon is a discrete quantum of electromagnetic radiation which has energy E, where E = hf, f being the frequency [2]

The correct description of a photon as a *quantum* of *electromagnetic radiation* is given. Full marks awarded.

***Candidate B***

A photon is a packet of energy or a quantum of electromagnetic radiation. [2]

The correct link between packets of energy and electromagnetic radiation is stated. Full marks awarded.

***Candidate E***

A photon is packet of energy whose energy ~~E~~ is; E=hf ; where f is the frequency of the photon. ~~Photons~~ Light is made up of photons. [2]

Full marks awarded for the nature of photons.

**(ii)** Explain how lines in the emission spectrum of gases at low pressure provide evidence for discrete electron energy levels in atoms.

***Candidate A***

~~To~~ These spectra ~~...~~ consist of bright lines against a dark background. This demonstrates that electrons in the gas atoms absorb energy in a discrete manner ~~...~~ to be excited, [2]
since when they relax back to their ground state, they emit light in a discrete manner.

In this section, the candidate does not link the bright lines observed to the energy levels in the atoms. Full marks would have been gained had the candidate linked the statement about *bright lines* to the photons having particular energies. The second mark requires the statement that the discrete energies are generated by transitions of the electrons between discrete energy levels in the atom. They *emit light in a discrete manner* is not a sufficient answer. No marks awarded.

***Candidate B***

The lines are distinct, ~~hence~~ and have different colours hence, proving the existence of discrete electron energy levels. [2]

The candidate does not link the colours of the lines to discrete energies of the photons resulting from discrete changes in the electron energies. See the comment on the answer for the grade A candidate.

***Candidate E***

The lines represent the energy absorbed by the electrons. This absorbtion can only occur when the electrons move ~~from~~ a change ~~levels~~ energy levels in an atom. [2]

The candidate talks about absorption when the question asks about emission. A common error with weaker candidates. The link between the lines and discrete energy changes is not made in the answer. No marks awarded.

**(c)** Three electron energy levels in atomic hydrogen are represented in Fig. 7.1.

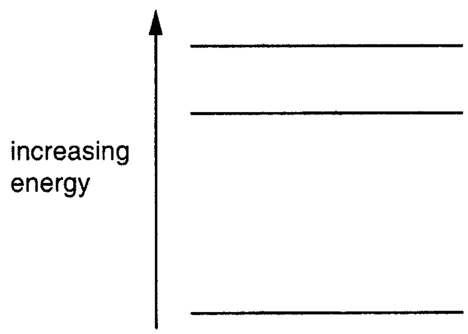



**Fig. 7.1**

The wavelengths of the spectral lines produced by electron transitions between these three energy levels are 486 nm, 656 nm and 1880 nm.

**(i)** On Fig. 7.1, draw arrows to show the electron transitions between the energy levels that would give rise to these wavelengths.
Label each arrow with the wavelength of the emitted photon. [3]

***Candidate A***

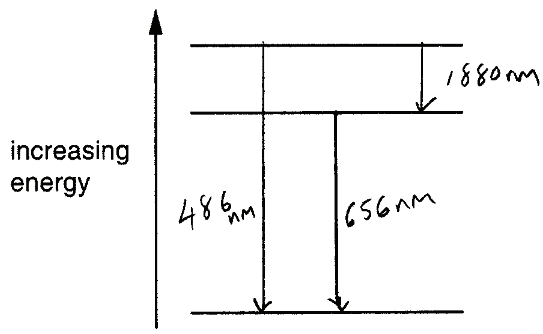
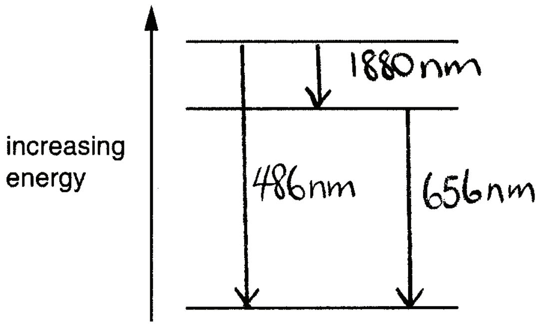



**Fig. 7.1**

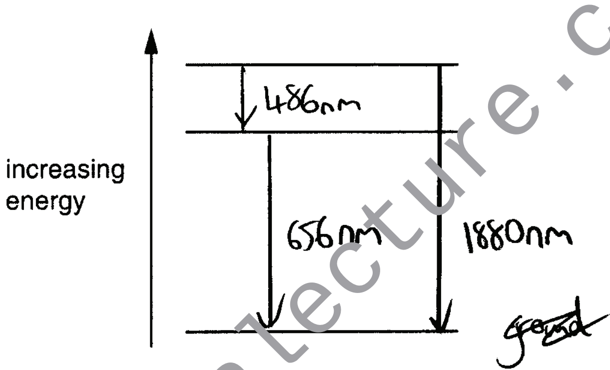
Three correct transitions labelled on the diagram with arrows to indicate an emission spectrum.

***Candidate B***




A correct diagram is drawn; full marks awarded.

***Candidate E***




The three energy changes are drawn with correct arrows, but the wavelengths are not attached to the correct transitions. Two marks awarded.

**(ii)** Calculate the maximum change in energy of an electron when making transitions between these levels.

***Candidate A***

$\Delta E = \frac{hc}{\Delta\lambda}$

∴ maximum change in energy occurs when $\Delta\lambda$ is minimum.

$\Rightarrow \Delta\lambda = 486\,\text{nm}$

$\Delta E = \frac{h \times c}{\Delta\lambda} = \frac{6.63\times10^{-34} \times 3\times10^{8}}{486\times10^{-9}} = 4.09\times10^{-19}$

energy = $4.09 \times 10^{-19}$ J [3]

A correct solution to the numerical part of the question. Full marks awarded.

***Candidate B***

Maximum change in energy $= E_1 - E_2$

$= \frac{hc}{\lambda_1} - \frac{hc}{\lambda_2}$

$= (6.63\times10^{-34} \times 3\times10^{8})\left(\frac{1}{486\times10^{-9}} - \frac{1}{880\times10^{-9}}\right)$

$= 3.03\times10^{-19}\,\text{J}$

energy = $3.03\times10^{-19}$ J [3]

The candidate correctly gives the basic equation relating energy to wavelength, but is then confused about how this relates to the wavelength values given in the question. There is confusion with the equation $E_2 - E_1 = hc/\lambda$.

***Candidate E***

$F = \frac{E_1 - E_2}{h}$ ; $F(E_2 - E_1)$

~~F~~ F is ~~for~~ greater when $E_1 - E_2$ is large

~~$E_1 E_2 = Fh =$~~

~~$E_1 - E_2 = Fh$~~

$\Delta E_{MAX} = F_{MAX} h$

$= 1880 \times 6.63\times10^{-34}$

energy = $1.246\times10^{-39}$ J [3]

The first line of text requires the correct substitution of $\lambda$ and $c$ to gain the first mark. The candidate then makes the fundamental error of thinking that the maximum energy change is associated with the largest wavelength. No marks awarded.

# Question 10

## General comments

**Candidate A**

An excellent answer to this question, demonstrating a clear understanding of the physics of operational amplifier circuits with two minor omissions.

**Candidate B**

A very good answer to this question with similar answers to the grade A candidate except for two points missed in **(a)(i) part 2** and one major mistake in **(a)(ii)**. Exam nerves?

**Candidate E**

A typical answer from a grade E candidate showing a limited knowledge of the physics involved in operational amplifiers, but unable to provide any of the mathematical detail required.

## Specific comments

**(a)** The circuit for an amplifier incorporating an ideal operational amplifier (op-amp) is shown in Fig. 10.1.

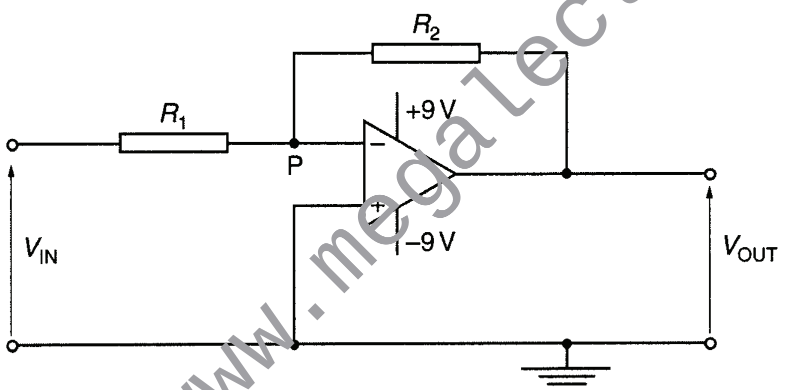



**Fig. 10.1**

**(i)** State

***Candidate A***

**1.** the name of this type of amplifier circuit,

inverting amplifier [1]

**2.** why the point P is referred to as a *virtual earth.*

the non-inverting input is at 0V so P is near to 0 ~~to~~ so that the output is not saturated. Ideal op-amp has ~~high~~ infinite input impedance so no current enters the inverting input, ~~thus P~~ The current flows through $R_2$ is equal to the current through $R_1$. Thus P is at virtual earth. [3]

1. Full marks for a correct identification of the circuit.

2. There are three independent marks for this section. The candidate scores two of them but misses the very important point that they only apply and make P a virtual earth if the open loop gain of the amplifier is very large and close to infinity. A point missed by many candidates.

***Candidate B***

**1.** the name of this type of amplifier circuit,

~~Negative feedback~~ Inverting amplifier (negative feedback) [1]

**2.** why the point P is referred to as a *virtual earth.*

This is because P is said to be at ~~zero~~ approximately zero potential, that is at earth's potential. There is nearly no difference in voltage between the inverting and non-inverting inputs. As non-inverting input is earthed, P being near the inverting input is at zero potential. [3]

1. Full marks for a correct identification of the circuit.

2. The candidate picks up one of the three marks in the next section for stating that the *non-inverting input is earthed*. The other two points relating to an infinite gain and the amplifier not saturating are missing.

***Candidate E***

**1.** the name of this type of amplifier circuit,

Inverting amplifier [1]

**2.** why the point P is referred to as a *virtual earth*.

~~For this circuit,~~ ~~the~~ $V_{IN}$ must be equal to ~~the~~ $V_o$ and since $V_{IN}$ is connected to the earth which is at 0 potential, $V_o$, being connected to P must be 0 too and hence P is referred to as virtual earth. [3]

Just one mark gained in this section for a correct identification of the type of amplifier circuit.

**(ii)** Show that the gain *G* of this amplifier circuit is given by the expression

$$G = -\frac{R_2}{R_1}.$$

Explain your working.

***Candidate A***

the current flows through $R_1$ = current flows through $R_2$

$$\frac{Vin}{R_1} = \frac{Vout}{R_2}$$

but Vout is in antiphase with Vin as ~~this~~ Vin is directed into the inverting input

so $$\frac{Vin}{R_1} = \frac{-Vout}{R_2}$$

$$\frac{Vout}{Vin} = -\frac{R_2}{R_1}$$

gain, $G = \frac{Vout}{Vin} = -\frac{R_2}{R_1}$ [4]

Three independent marks for this section. Again the candidate scores two, missing the important point that, for the current in $R_1$ and $R_2$ to be the same, the input resistance of the amplifier must be very large. A point missed by many candidates.

***Candidate B***

$$\text{Gain} = \frac{V_{out}}{V_{in}}$$

$V\ out = IR_2$ where $I$ = current in circuit.

$V_{in} = IR_1$

$$\Rightarrow G = \frac{V_o}{V_1} = \frac{IR_2}{IR_1} = -\frac{R_2}{R_1}$$

, –ve since the inverting input is connected and the non-inverting input is earthed.

[4]

Nothing mark-worthy in this section as *I = the current in the circuit* is not sufficient without an identification of which current is being referred to. The answer is also missing a statement that the input resistance of the operational amplifier is very large. The mathematics that follows is thus meaningless, and also a minus sign crossed out in the second line text suddenly appears in the last line!

***Candidate E***

$$\frac{V_o}{V_{IN}} =$$

$$V_o = \frac{R_1}{R_1 + R_2} V_{IN}$$

$$\frac{V_{IN}}{V_{OUT}} = \frac{R_1 + R_2}{R_1} \quad \frac{R_1 + R_2}{R_1}$$

$$\frac{V_{IN}}{V_o} = \frac{R_1}{R_1} + \frac{R_2}{R_1}$$

[4]

$$\frac{V_{IN}}{V_o} = \frac{R_2}{R_1}$$

There is no identification of any current flowing in the circuit so the written equations are meaningless.

**(b)** The circuit of Fig. 10.1 is modified by connecting a light-dependent resistor (LDR) as shown in Fig. 10.2.

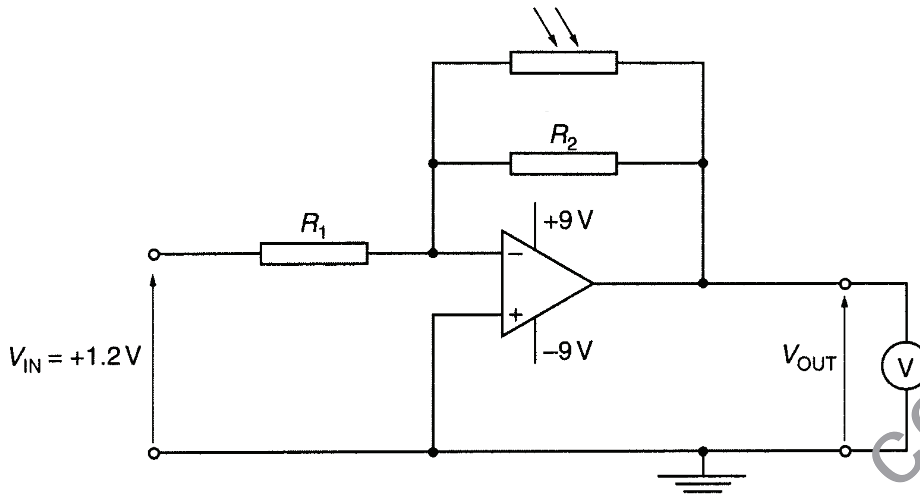



**Fig. 10.2**

The resistances $R_1$ and $R_2$ are 5.0 kΩ and 50 kΩ respectively.
The input voltage $V_{IN}$ is +1.2 V. A high-resistance voltmeter measures the output $V_{OUT}$.
The circuit is used to monitor low light intensities.

**(i)** Determine the voltmeter reading for light intensities such that the LDR has a resistance of

***Candidate A***

**1.** 100 kΩ,

gain, G $= -\frac{\left(\frac{1}{50\times10^3}+\frac{1}{100\times10^3}\right)^{-1}}{5.0\times10^3}$

$= -\frac{20}{3}$

Vout $= -\frac{20}{3}$ Vin

$= -\frac{20}{3}(1.2)$

$= -8$ V

reading = −8 V [3]

**2.** 10 kΩ.

gain, G $= -\frac{\left(\frac{1}{50\times10^3}+\frac{1}{10\times10^3}\right)^{-1}}{5.0\times10^3}$

$= -\frac{5}{3}$

Vout $= -\frac{5}{3}$ Vin

$= -\frac{5}{3}(1.2)$

$= -2$ ✓

reading = −2 V [2]

A correct calculation of the two voltmeter readings gains full marks.

***Candidate B***

**1.** 100 kΩ,

Resistance of LDR and $R_2$

$\Rightarrow \frac{1}{R_T} = \frac{1}{100\times10^3} + \frac{1}{50\times10^3}$

$R_T = 33333\,\Omega$

Gain $= \left(\frac{R_T}{R_1}\right) = \frac{V_0}{V_i}$

$V_0 = 8\text{V}.$

reading = −8.0 V [3]

**2.** 10 kΩ.

Total resistance of LDR and $R_2$

$\Rightarrow \frac{1}{R_T} = \frac{1}{10\times10^3} + \frac{1}{50\times10^3}$

$R_T = 8333\,\Omega$

Gain $= -\left(\frac{R_T}{R_1}\right) = \frac{V_0}{V_i}$

$V_0 = \frac{8333}{5.0\times10^3} \times 1.2$

$= 2.0\text{V}$

reading = −2.0 V [2]

Full marks for two correct solutions.

***Candidate E***

**1.** 100 kΩ,

~~$V = \frac{100}{\left(\frac{1}{100} + \frac{1}{50}\right)} \times 1.2$~~

~~$= 4000$~~

$V = \frac{100}{100+5} \times 1.2$

reading = 1.14 V [3]

**2.** 10 kΩ.

~~$V = \frac{10}{\left(\frac{1}{10} + \frac{1}{50}\right)} \times 1.2$~~

$= 100$

$V = \frac{10}{(10+5)} \times 1.2$

$= 0.8$

reading = ~~100V~~ 0.8 V [2]

Nothing worth any marks in this section. The value of 100 used in the one line of mathematics does not relate to any values given in the question.

**(ii)** The light incident on the LDR is provided by a single lamp. Use your answers in **(i)** to describe and explain qualitatively the variation of the voltmeter reading as the lamp is moved away from the LDR.

***Candidate A***

when the lamp is near to the LDR, the resistance on the LDR is ~~high~~ low so the magnitude of the voltmeter reading is small. As the lamp moves away from the LDR, intensity of light on the LDR decreases and the resistance increases. Voltmeter reading thus increases. [3]

The candidate clearly states what happens when the lamp moves away, the light intensity decreases, and continues to explain how this leads to an increase in the output voltage. Full marks.

***Candidate B***

Vout becomes larger. As lamp is moved away the light intensity falling on the LDR decreases, hence, resistance of LDR increases. From results obtained the Vout becomes larger. [3]

Full marks for this section with the candidate clearly linking the reduction in light intensity with a decrease in the resistance of the LDR.
Many candidates lost this mark by stating that as the light intensity decreases the *resistance decreases* with no reference to the LDR or the total feedback resistance.

***Candidate E***

As the lamp is moved away the light intensity decreases; the resistance across the LDR is high and the voltage ~~also is higher~~ across the LDR decreases. [3]

Two marks awarded in this section, *as the lamp moves away the light intensity decreases* and benefit of doubt given for *the resistance across the LDR is high*. The candidate does not state what happens to the voltmeter reading.

# Question 11

## General comments

**Candidate A**

An excellent answer to this question with the candidate showing an extensive knowledge of both X-ray techniques and CT scanning.

**Candidate B**

The candidate indicates a good knowledge of the difference between the two imaging techniques, but misses some detail on the principles involved in CT scanning.

**Candidate E**

This candidate shows some basic knowledge of CT and X-ray imaging, but the answers lack detail.

## Specific comments

**(a)** **Distinguish between the images produced by CT scanning and X-ray imaging.**

***Candidate A***

Images produce from X-ray imaging are 2 dimensional and they give no impression of depth whereas CT scanning produces 3 ~~d~~ dimensional images that gives an impression of depth.

..................... [3]

The candidate realises that the difference between the two systems is that one produces a 2D image and the other a 3D image, but misses the point that the 3D image is constructed from sets of 2D slices.

***Candidate B***

X-ray images are 2-dimensional CT scan creates slices of the body section, and builds up these slices on a computer to produce a 3-dimensional image, which can then be rotated around with [3]

An excellent answer gaining full marks. The candidate realises that the CT image is constructed from a series of 2D slices, a point missed by many candidates.

***Candidate E***

(1) The image produced by CT scan is 3d while for X-ray is 2d.
(2) The image by CT scan is taken from different angle.
(3) Image by CT can be more improved by using a computer while for X-ray we cannot. [3]

The candidate knows that the CT scan produces a 3D image and the X-ray scan a 2D image, but fails to state that the 3D image is constructed from 2D slices.

**(b)** **By reference to the principles of CT scanning, suggest why CT scanning could not be developed before powerful computers were available.**

***Candidate A***

In CT scanning, ~~seve~~ several X-rays of a slice are taken at different angles but in the plane of the slice. Many slices of a body are X-rayed in CT scanning and vast amounts of information are obtained. The computer then combines all of these slice ~~imp~~ images to form one 3-dimensional image and the mathematics and calculations involved in this process is very demanding. Only powerful computers can process [5] such vast amounts of data in such a way.

This question is in two parts requiring the candidate to explain the principles of CT scanning followed by a reason why computers are required. This excellent answer from the grade A candidate gives just the required amount of detail to gain four marks for the principles section and then clearly states why computers are required, *to process such vast amounts of data*.

***Candidate B***

CT scanning divides the body section up into millions of sections called voxels each with a pixel intensity. It scans from a large number of different angles to derive the pixel intensity for every voxel in a slice of the body. These then need to be processed and put together with all the other slices, and millions of computations are required for the final 3D image, and hence powerful computers are required for CT scanning. [5]

It is clear from this answer that the candidate understands the principles of CT scanning, but the answer provided lacks detail. The introduction of the term voxels, often referred to by many candidates, is of little use without a statement which specifies how the intensity in each voxel is obtained. *It scans from a large number of angles* does not give enough detail as it requires an initial statement as to what scans. In using the term *these* in the next sentence it is again unclear whether the candidate is referring to the intensities or the slices described in the previous sentence. With just a little more precision in describing the process, this answer would easily gain full marks. Two marks are gained for the reason a computer is required and how a 3D image is obtained.

***Candidate E***

(1) There was not ~~the~~ ~~[illegible]~~ ~~the~~ computer programs to combine the images obtained to form 3d images.
(2) With powerful computers, we can increased the intensity to obtain more details in order to improve the image.
(3) [5]

A mark is given for the information that the computer is used to combine images to form a 3D image. The second statement needs elaboration to gain a mark; *more detail* is too vague. As an example, more detail could be that the image can be rotated.

**Candidate A**

The candidate appeared to complete the question paper in the time available. The candidate scored highly on both questions. Marks were not gained in Question 1 because of a lack of detail. In Question 2, a mark was lost because of a power of ten error on reading information from the graph, and the final mark was not awarded. It was pleasing to see that the plan was logically written.

**Candidate B**

The candidate appeared to complete the question paper in the time available. The candidate gained reasonable marks on both questions. Marks were not gained in Question 1 because of a lack of detail and, in Question 2, marks were lost at the end of the question where careful attention to detail was needed. It was pleasing to see that the plan had a very good diagram.

**Candidate E**

The candidate appeared to complete the question paper in the time available. The candidate scored low marks on both questions. Marks were not gained in Question 1 because of a lack of detail and disappointing diagrams. In Question 2, the candidate did not score marks on the analysis sections, which is a common trait in weaker candidates' scripts.



## Question 1

A student wishes to investigate how the resistance *R* of a light-dependent resistor varies with the distance *d* from an intense light source.

It is believed that the relationship between *R* and *d* is

$$R = kd^n$$

where *k* and *n* are constants.

Design a laboratory experiment to test the above relationship. The light-dependent resistor has a resistance of 100 Ω when it is in bright light and a resistance of 500 kΩ when no light falls on it.

You should draw a diagram showing the arrangement of your equipment. In your account you should pay particular attention to

**(a)** the procedure to be followed,

**(b)** the measurements that would be taken,

**(c)** the control of variables,

**(d)** how the data would be analysed,

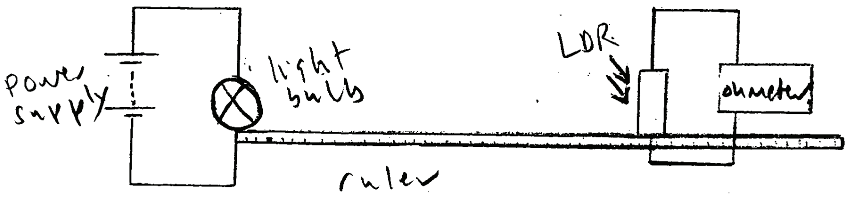
**(e)** any safety precautions that you would take.

[15]

# Paper 5 Planning, Analysis and Evaluation

***Candidate A***

**Diagram**




The independent variable is the distance of the light-dependent resistor is from the light source (bulb). The dependent variable is the resistance of the light-dependent resistor. A variable to be kept constant is the light intensity of the bulb. Set up the experiment as per diagram by connecting a very bright (powerful) light bulb to the power supply and the LDR to an ohmeter. Place both the light bulb and the LDR on a horizontal surface (eg desktop) so that they are directly facing each other. Measure the independent variable, the distance with a metre ruler accurate to 1mm. Measure the dependent variable, the resistance with the ohmeter. Keep the light intensity of the bulb constant by setting the power supply to supply electricity at a constant EMF and wait for the bulb to heat up to a constant temperature to allow res resistance to stabilize and this will ensure a constant current, so the intensity of the bulb is constant. A second variable to be kept constant is the lighting condition of the room, the best way to keep this constant is to do the experiment in a dim room with the lights off and the curtains closed so that the only source of light is the bulb. Vary the distance by moving the LDR away from or towards the bulb and record the resistance at each distance, in the same table record the values of log R and log d. Plot a graph of log R (y-axis) against log d (x-axis) because $R = kd^n$

$\therefore \log R = \log k + n \log d$

$y = c + mx$, if a linear relationship is seen (i.e a straight line) then hypothesis is confirmed. The value of n is equal to the gradient and the value of k is equal to $10^{y\text{-intercept}}$. A safety concern is that the bulb may get very hot, so heat insulative gloves should be worn when disconnecting ie after the experiment has finished, or leave it to cool. Another safety concern is that the bulb may be over bright and cause dizziness, so sunglasses should be worn throughout the experiment. When connecting the LDR to the ohmeter, use short thick wires to ~~minimise~~ reduce the ~~error~~ resistance of the connecting wires to minimise error, and use crocodile clips to securely attach wires to the LDR. Obtain a large range of values for the resistance, especially when the distance is large, because the greater the distance the higher the resistance so the lower percentage error of resistance measured, when the distance is small, the measured distance may be very inaccurate.

The first part of Question 1 requires candidates to draw a diagram of the arrangement of the equipment. The candidate's diagram scored full marks. The diagram was labelled clearly and correct symbols were used for both circuits; it was also neat. The candidate clearly indicated both the distance that was to be measured and how that distance was to be measured with a ruler. In this case the candidate used an ohmmeter correctly; a common error would be to include a power supply or battery in the ohmmeter circuit.

There is then a page and a half for candidates to write a description of their plan. This candidate begins sensibly by defining the problem by correctly identifying that the distance is the independent variable and the resistance of the LDR is the dependent variable, gaining both P1 and P2. It is clear from the response that the candidate understands the problem. It is expected that candidates will identify variables that need to be kept constant so as to enable a fair test to be made; again the candidate indicates clearly the need to keep the intensity of the light source constant, gaining P3. Weaker candidates often refer to 'controlling' variables which does not gain credit.

In the text the candidate clearly indicates that the resistance of the LDR will be measured with the ohmmeter. Other good candidates would discuss calculating the value of resistance from the reading on a voltmeter and ammeter for this mark. The candidate gained an additional detail mark for the method of keeping the light intensity constant by using a constant emf and waiting for the bulb to heat up to a constant temperature. Other good candidates often went into detail about how the light intensity would be kept constant, e.g. adding a rheostat and ammeter in the circuit containing the lamp and adjusting the rheostat so that the ammeter reading (current) is constant.

A further method mark was awarded for the candidate's realisation that the experiment should be carried out in room with the lights turned off and the curtains closed so the only source of light is the bulb.

There are two marks available for the method of analysis. The candidate initially indicated that values of log *R* and log *d* would be recorded in the table, before scoring the A1 mark for a statement that a graph of log *R* (*y*-axis) against log *d* (*x*-axis) would be plotted. Having suggested an appropriate graph, the A2 mark in this section is awarded for the correct identification of how the relationship suggested would be confirmed; the candidate's wording of this section was very clear – "if a linear relationship is seen (i.e. a straight line) then the hypothesis is confirmed". This candidate also scored an additional detail mark for correctly identifying both the gradient and the *y*-intercept from the logarithmic equation that the candidate has clearly indicated.

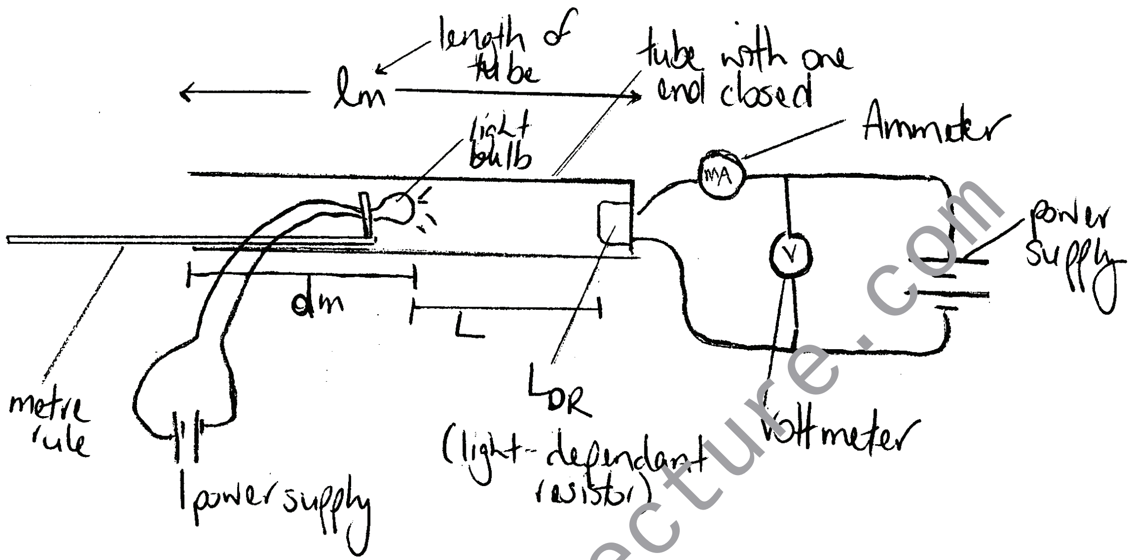
The candidate scores the safety mark since the hazard is stated "bulb may get very hot" and a suitable precaution is given "heat insulative gloves should be worn". The candidate also suggested that the bulb may be 'overbright' and thus sunglasses should be worn – this would have gained credit since the candidate had identified the hazard (intense, bright light) and suggested a safety precaution. Valid reasoning is required for the award of this mark. A more general precaution of switching off the power supply to prevent heat in light bulb, resistor and LDR did not gain credit.

The end of the candidate's plan did not score any further marks. The use of short, thick wires for making connections is not specific to this particular experiment; the obtaining of a large range of values for resistance applies to any experiment. The candidate was beginning to make a relevant point when discussing the errors in the measurements at different distances.

This candidate could have gained additional detail marks for determining a typical current in the LDR and then specifying the range on the ohmmeter and by providing some detail about keeping the orientation of the LDR constant, with a method as to how this could be achieved.

***Candidate B***

**Diagram**




(a) Set up the experiment (as shown) above. Measure the distance between the LDR and the lightbulb $(l_m - d_m)$ m in the above experiment. At this distance, note the current recorded and the voltage recorded. Repeat the experiment by varying the length of d (to obtain varying distance between lightbulb and the LDR, L) then record the current and voltage with different distance L.

(b) Measure different value of L by varying d. L will give the distance between the lightbulb and the LDR. Measure the value of Current, by using the ammeter and record the voltage (V) using the voltmeter. The resistance R then could be obtained using the formula $R = \frac{V}{I}$.

# Paper 5 Planning, Analysis and Evaluation

(c) The length of the tube should be the same in all experiment. The power (current) supply to the LDR and the lightbulb should be keep constant throughout the experiment or else if the power supply is varied, different current and voltage will be recorded with varying distance L.

(d) Plot a graph of log R on y axis against log d on the x-axis and see the relationship. The gradient of the graph will give the value of n.

(e) 1/ Cover the open end of the tube with a black cloth to make sure that only light from the lightbulb is received by the LDR (or else surrounding light might be also received by the LDR affecting the recorded value of current and voltage.
2/ Make sure the lightbulb is not too close to the LDR to prevent the damage on LDR due to high light intensity.
3/ Make sure your hand is dry throughout the experiment to prevent electric shock because of current in the connecting wire.
4/ Make sure that the two connected wire on the LDR do not touch each other to prevent the fuse to blow up.

The first part of Question 1 requires candidates to draw a diagram of the arrangement of the equipment. The candidate's diagram scored full marks. The diagram was labelled clearly and it was neatly drawn. The candidate clearly indicates that the lamp is in a separate circuit to the LDR and the distance that was to be measured. To determine the resistance of the LDR, the candidate draws an appropriate circuit diagram including an ammeter and voltmeter correctly positioned; weaker candidates often positioned the meters incorrectly. The diagram also included a tube which gained a mark for further methods of data collection. This script clearly indicates the benefit of drawing a good, labelled diagram.

There is then a page and a half for candidates to write a description of their plan. This candidate begins by discussing the distance from the intense light source. There is some confusion between the letters used by the candidate and the Question. In the first paragraph, the first mark for defining the problem is gained by correctly identifying that the distance is the independent variable, with the statement that the experiment is repeated by varying the length of *d*. The candidate then discusses recording the raw data of current and voltage for different length *L*. In the second paragraph, the candidate explains how the resistance would be determined. It is expected that candidates will identify variables that need to be kept constant so as to enable a fair test to be made; this does not occur immediately.

In the next paragraph, the candidate tries to identify a variable to keep constant. The candidate implies that the power supply to the lamp is kept constant, but credit was not given since it was not clear and the candidate appeared to be confused about the LDR and the lamp.

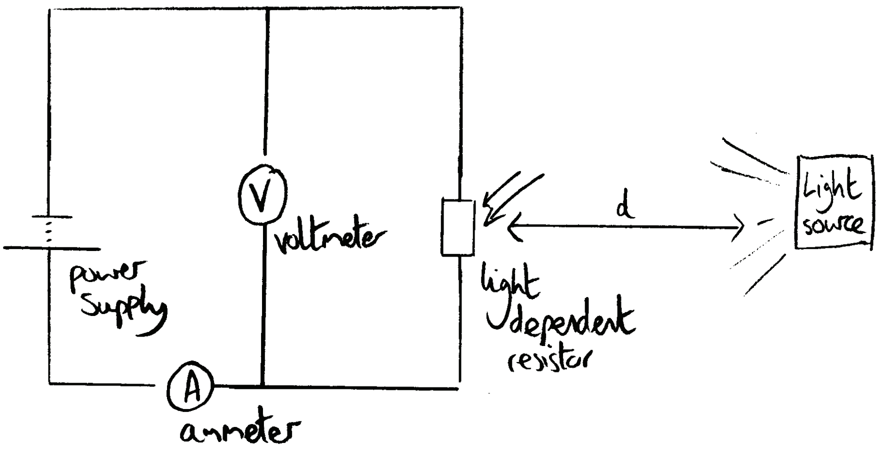
There are two marks available for the method of analysis. The candidate states that a graph of log *R* on the *y*-axis against log *d* on the *x*-axis is plotted. Having suggested an appropriate graph, the A2 mark in this section is awarded for the correct identification of how the suggested relationship would be confirmed; the candidate omitted this part but did gain an additional detail mark for stating that the gradient would give the value of *n*.

The candidate has omitted to detail a relevant safety precaution related to the intense light source. Valid reasoning is required for this mark to be awarded. The end of the candidate's plan did not score any further marks.

This candidate could have gained additional detail marks for determining a typical current in the LDR and then specifying the range on the ohmmeter, and giving some detail about keeping the orientation of the LDR constant with a method as to how this could be achieved.

***Candidate E***

**Diagram**




(c) Dependent Variable: Resistance, R of light dependent resistor (LDR)
Independent variable: distance d, separating LDR from light source.
Variables to be controlled: resistivity of LDR, Intensity of light

(a) The apparatus is setup as shown in Figure 1.1.
The electrical circuit is setup. The voltmeter is connected in parallel with LDR and in series with ammeter.
The light dependent resistor should be facing the light source.

(b) Measure the distance, d separating the ~~light depe~~ LDR from the light source using a metre rule.
Switch on the power supply.
Record the value of V, voltmeter reading, A, ammeter reading.

# Paper 5 Planning, Analysis and Evaluation

Vary the distance d by moving the light source nearer or away from the LDR.
Take a new set of readings for this value d.
Draw up a table of values containing the following sets of readings: d/m, I/A, V/V.
Add another value for R/Ω
using Ohm's Law.
V=IR, calculate R for respective value of d.
Vary d by small values to obtain more accurate readings.
Do not put the light source too close to the LDR, otherwise high voltages will be reached, hence introducing errors.
Switch off the power supply at some intervals to prevent overheating of apparatus.
Make sure there are no other sources of light in the surroundings or perform the experiment in a dark room.

(d) ~~Plot a graph of R against d~~ $R = kd^n$, Introduce Lg
$\lg R = \lg k + n \lg d$.
Plot a graph of lg R v/s lg d, hence Lg k will give value of y-intercept and n that of gradient.
A straight line not passing through origin should be obtained.

(e) - Do not handle water ~~or~~ during the experiment ~~or the electri experimenter~~ can get ~~electrocuted~~ electric shock
- Do not place the light source too close to the LDR, high voltages may burn the apparatus and burn the person handling them.
- Do not touch the apparatus when power supply is still on.

The first part of Question 1 requires candidates to draw a diagram of the arrangement of the equipment. The candidate's diagram was carelessly drawn. There was evidence of understanding that the light source needed to be separate from the LDR circuit. However, the distance to be measured was not accurate and the circuit diagram (although basically correct) did not have the connections fully made at the ammeter or the voltmeter. Other common errors made by weaker candidates were to connect the meters incorrectly. Some weaker candidates connected an additional resistor into the circuit and then connected the voltmeter across the additional resistor rather than across the LDR.

There is then a page and a half for candidates to write a description of their plan. This candidate begins sensibly in defining the problem by correctly identifying that the distance is the independent variable and the resistance of the LDR is the dependent variable, gaining both P1 and P2. It is clear from the response that the candidate understands the problem. It is expected that candidates will identify variables that need to be kept constant so as to enable a fair test to be made; the candidate indicates 'variables to be controlled' which does not gain credit. A statement stating which variables will be kept **constant** in required.

In the text, the candidate clearly indicates how the experiment will be carried out. Again P1 and P2 could be awarded on the basis of the text. The candidate also discusses calculating the value of resistance from the reading on a voltmeter and ammeter and using $V = IR$. A further method mark was awarded for the candidate's statement that there should not be any other sources of light in the surroundings, or the experiment should be performed in a dark room. Either of these statements would have gained credit.

There are two marks available for the method of analysis. The candidate scores the A1 mark for plotting a graph of "lg $R$ v/s lg $d$". This candidate also scored an additional detail mark for correctly identifying both the gradient and the $y$-intercept from the logarithmic equation, which the candidate has clearly indicated. Having suggested an appropriate graph, the A2 mark in this section is awarded for the correct identification of how the suggested relationship would be confirmed; the candidate's wording of this section was almost worthy of the second mark but it missed out "if the relationship is confirmed".

The candidate did not gain the safety mark since the suggestions were not really relevant to the experiment. It was expected that the safety precautions would relate to the intense light source either being hot or bright. Valid reasoning is required for the award of this mark. Some weaker candidates list precautions such as tying hair back, wearing goggles, not handling water, follow lab rules, etc. which do not gain credit.

This candidate could have gained additional detail marks: detail about how the light intensity would be kept constant, e.g. adding a rheostat and ammeter in the circuit containing the lamp and adjusting the rheostat so that the ammeter reading (current) is constant; for determining a typical current in the LDR and then specifying the range on the ohmmeter; or for some detail about keeping the orientation of the LDR constant with a method as to how this could be achieved. The candidate started making this last point, suggesting that the LDR should be facing the light source, but more detail would be needed for the award of the mark.

## Question 2

An experiment was carried out to investigate how the diameter *d* of the path of a beam of electrons varied with the accelerating voltage *V* when a magnetic field of flux density *B* was applied at right angles to the electron beam.

The equipment was set up as shown in Fig. 2.1.

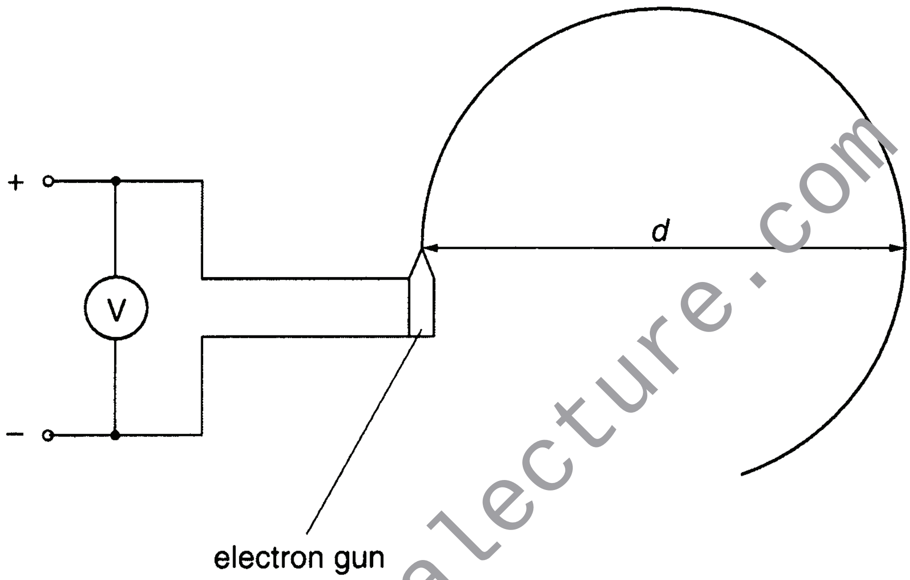



**Fig. 2.1**

The diameter *d* was recorded for different voltages *V*.

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***Candidate A***

Values of *V* and *d* are given in Fig. 2.2.

| *V*/V | *d*/$10^{-2}$m | $d^2/10^{-4}m^2$ |
|---|---|---|
| 500 | 2.1 ± 0.1 | 4.4 ± 0.4 |
| 1000 | 2.8 ± 0.1 | 7.8 ± 0.6 |
| 1500 | 3.4 ± 0.1 | 11.6 ± 0.7 |
| 2000 | 3.9 ± 0.1 | 15.2 ± 0.8 |
| 2500 | 4.3 ± 0.1 | 18.5 ± 0.9 |
| 3000 | 4.7 ± 0.1 | 22.1 ± 1.0 |

**Fig. 2.2**

It is suggested that *V* and *d* are related by the formula

$$\frac{e}{m} = \frac{8V}{B^2d^2}$$

where *e* is the charge on the electron and *m* is the electron mass.

**(a)** A graph of $d^2$ on the *y*-axis against *V* on the *x*-axis is to be plotted. Write down an expression for the gradient in terms of *e*, *m* and *B*.

$\frac{e}{m} = \frac{8V}{B^2d^2}$ $\quad d^2 = \frac{8mV}{B^2e} = \frac{8m}{B^2e}V$ $\quad \therefore$ gradient $= \frac{8m}{B^2e}$

$\frac{d^2e}{m} = \frac{8V}{B^2}$ $\quad y = mx$

$\frac{8m}{B^2e}$ [1]

**(b)** Calculate and record values of ($d^2$ / $10^{-4}$ $m^2$) in Fig. 2.2. Include in the table the absolute errors in $d^2$. [3]

**(c)** **(i)** Plot a graph of $d^2$ on the *y*-axis against *V* on the *x*-axis. Include error bars for $d^2$. [2]

**(ii)** Draw the best-fit straight line and a worst acceptable straight line on your graph. Both lines should be clearly labelled. [2]

**(iii)** Determine the gradient of the best-fit line. Include the error in your answer.

gradient $= \frac{\Delta y}{\Delta x}$

$= \frac{20.4 - 7.0}{2750 - 850} = \frac{13.4}{1900} = 0.00705263...$

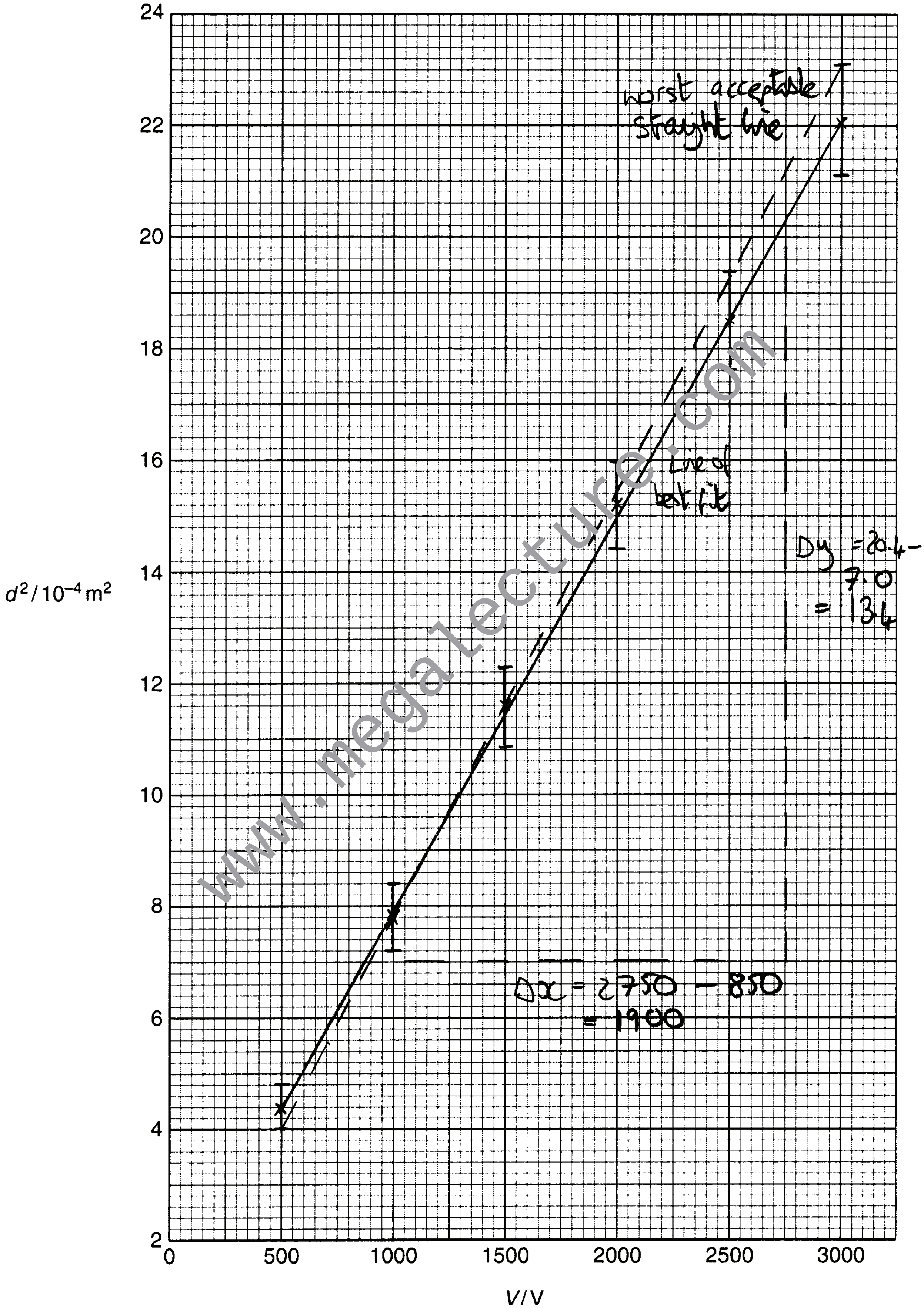
$= 7.05 \times 10^{-3}$ (3sf)

gradient (worst acceptable straight line) $= \frac{23.1 - 4.0}{3000 - 500} = \frac{19.1}{2500} = 7.64 \times 10^{-3}$

$\therefore$ error $= 7.64 \times 10^{-3} - 7.05 \times 10^{-3} = 0.59 \times 10^{-3}$

$\therefore$ gradient $= 7.05 \times 10^{-3} \pm 0.59 \times 10^{-3}$

gradient = $(7.05 \pm 0.59) \times 10^{-3}$ [2]


24
22
20
18
16
14
12
10
8
6
4
2
$d^2 / 10^{-4}$ m$^2$
0
500
1000
1500
2000
2500
3000
$V$ / V
worst acceptable straight line
line of best fit
Dy = 20.4 − 7.0 = 13.4
Dx = 2750 − 850 = 1900

**(d)** The magnetic flux density $B$ of the magnetic field is $7.9 \times 10^{-3}$ T. Using the answer to **(c)(iii)**, determine the value of $\frac{e}{m}$. Include the error in your value and an appropriate unit.

gradient $= \frac{8m}{B^2 e} = 7.05 \times 10^{-3}$ , $B = 7.9 \times 10^{-3}$

$\therefore \frac{8m}{(7.9 \times 10^{-3})^2 e} = 7.05 \times 10^{-3}$

$\frac{e}{m} = \frac{8}{(7.9 \times 10^{-3})^2 (7.05 \times 10^{-3})} = 1.82 \times 10^7$ (3sf) ( kg$^{-1}$

percentage error of gradient

$= \frac{0.59 \times 10^{-3}}{7.05 \times 10^{-3}} \times 100\% = 8.368...\%$

absolute error of $\frac{e}{m}$ = 8.368...% $\times 1.82 \times 10^7 = 0.15 \times 10^7$

$\frac{e}{m}$ = $(1.82 \pm 0.15) \times 10^7$ C kg$^{-1}$ [3]

**(e)** The experiment is repeated with a different magnetic flux density. When $V$ is 500 V, the measured value of $d$ is $(3.8 \pm 0.1) \times 10^{-2}$ m. Using your answer to **(d)**, determine a value for the new magnetic flux density, $B$. Include the error in your value.

$\frac{e}{m} = \frac{8V}{B^2 d^2}$

$B = \sqrt{\frac{8V}{d^2} \div \frac{e}{m}}$

$= \sqrt{\frac{8 \times 500}{(3.8 \times 10^{-2})^2} \div 1.82 \times 10^7}$

$= 0.390$ T

% error $= \dfrac{8.368... + \frac{0.1}{3.8} \times 100 \times 2}{2}$

$= 6.8155...$ %

absolute error = 6.8155...% $\times 0.390$

$\therefore B = 0.390 \pm 0.027$ T

$B$ = $0.390 \pm 0.027$ T [2]

Question 2 was very well answered. It was pleasing to see the candidate use clear methods.
The candidate correctly determined an expression for the gradient in terms of *e*, *m* and *B*. Again it is pleasing to see the candidate demonstrate the answer clearly.

The basic results table was calculated correctly with an appropriate number of significant figures given. The method of determining the absolute uncertainties was correct in all cases. Significant figures in uncertainties are not penalised in **(b)**. Thus the last uncertainty ±1 would have been accepted as well as the candidate's value of ±1.0.

The plotting of points and error bars was good; the points were clearly indicated and the ends of the error bars were clearly distinguished. Both the best fit and the worst acceptable lines were labelled – the candidate had dashed the worst acceptable line as well as labelling it using text. The line of best fit and the worst acceptable line were drawn carefully and were correct, the worst acceptable line clearly passing through the top of the top error bar and the bottom of the bottom error bar.

The candidate calculated both the gradient of the best fit line and the worst acceptable line correctly and thus determined the uncertainty in the gradient correctly from the difference in the two values. It was pleasing to see the triangle for the gradient clearly indicated on the graph and the values clearly seen. The power of ten error when reading off the *y*-axis is not penalised at this stage. The method for determining the uncertainty in the gradient was also clearly shown.

Part **(d)** was correct apart the power of ten error when calculating *e*/*m*. To determine the uncertainty in *e*/*m*, the candidate's method of finding the percentage uncertainty in the gradient and then applying this to *e*/*m* was correct. Fractional methods or working out *e*/*m* using the worst possible value for the gradient would also have scored this mark. The unit (C $kg^{-1}$) was clearly written down.

In **(e)** the candidate gained an answer within the specified range, allowing for the power of ten error that was penalised earlier. This candidate clearly showed the working. To calculate the absolute uncertainty in *B* the candidate uses the percentage uncertainty in *e*/*m* and then correctly adds it to 2 × the percentage uncertainty in *d*. Sadly the candidate then incorrectly divided the answer by two. This was a very good attempt. It should be noted that, although this method was not specified in the mark scheme, if the candidate had added the percentage error of 8.368% to twice the percentage error in *d*, then credit would have been scored for this part; this is an example where Examiners credit good physics which may not appear on the published markscheme.

# Paper 5 Planning, Analysis and Evaluation

***Candidate B***

Values of $V$ and $d$ are given in Fig. 2.2.

| $V$/V | $d$/$10^{-2}$m | $d^2$/$10^{-4}$m$^2$ |
|---|---|---|
| 500 | 2.1 ± 0.1 | 4.4 ± 0.4 |
| 1000 | 2.8 ± 0.1 | 7.8 ± 0.6 |
| 1500 | 3.4 ± 0.1 | 11.6 ± 0.7 |
| 2000 | 3.9 ± 0.1 | 15.2 ± 0.8 |
| 2500 | 4.3 ± 0.1 | 18.5 ± 0.9 |
| 3000 | 4.7 ± 0.1 | 22.1 ± 0.9 |

$\frac{\Delta d^2}{d^2} = \frac{2\Delta d}{d}$

$\Delta d^2 = \frac{2\Delta d}{d} \times d^2$

**Fig. 2.2**

It is suggested that $V$ and $d$ are related by the formula

$$\frac{e}{m} = \frac{8V}{B^2 d^2} \qquad = \frac{ms^{-2}}{T^2\ m^2}$$

where $e$ is the charge on the electron and $m$ is the electron mass.

**(a)** A graph of $d^2$ on the $y$-axis against $V$ on the $x$-axis is to be plotted. Write down an expression for the gradient in terms of $e$, $m$ and $B$.

$B^2 d^2 e = 8mV$

$d^2 = \frac{8m}{B^2 e} V$

$y = m x$

$\frac{8m}{B^2 e}$ [1]

**(b)** Calculate and record values of ($d^2$ / $10^{-4}$ m$^2$) in Fig. 2.2. Include in the table the absolute errors in $d^2$. [3]

**(c)** **(i)** Plot a graph of $d^2$ on the $y$-axis against $V$ on the $x$-axis. Include error bars for $d^2$. [2]

**(ii)** Draw the best-fit straight line and a worst acceptable straight line on your graph. Both lines should be clearly labelled. [2]

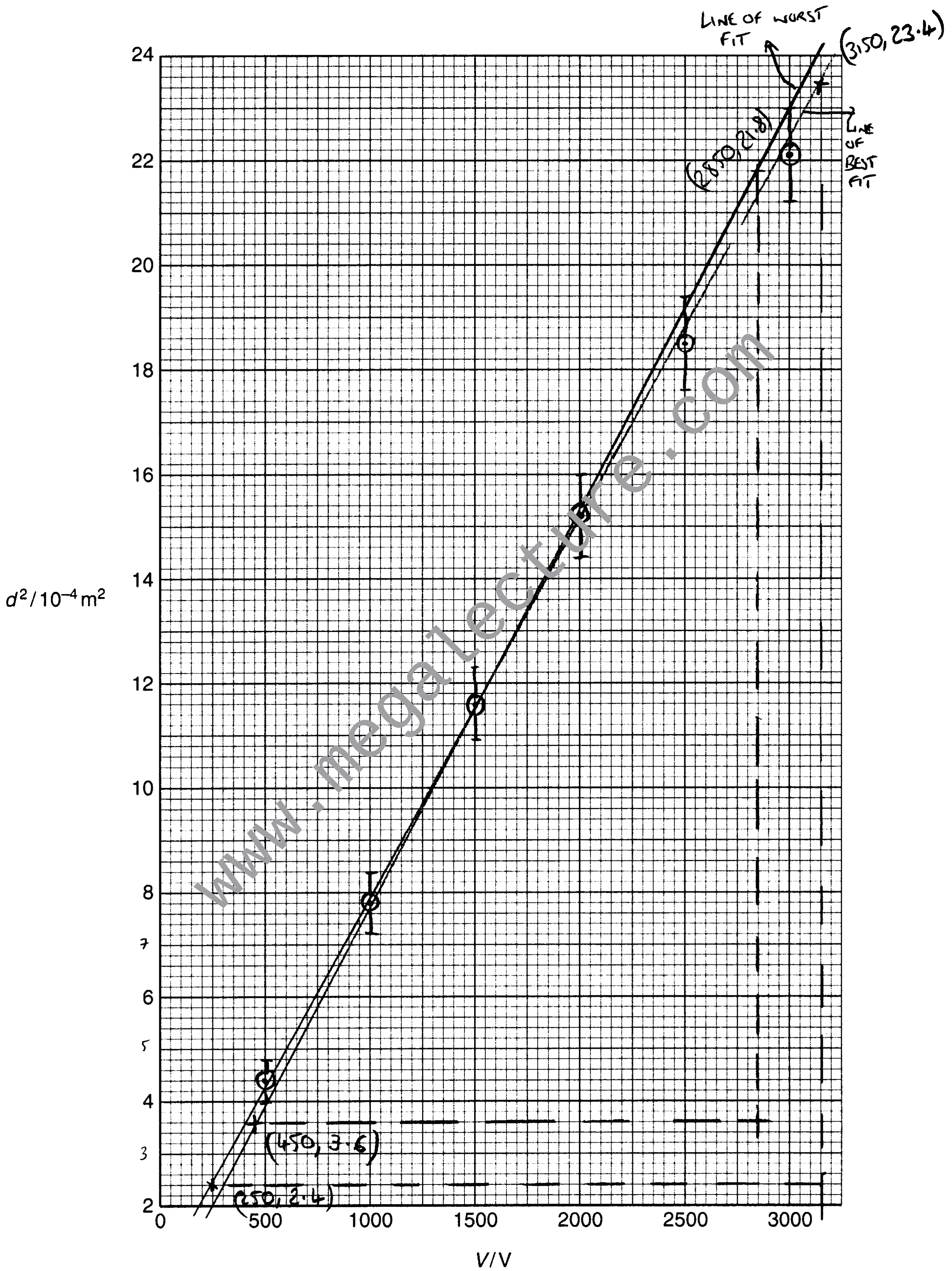
**(iii)** Determine the gradient of the best-fit line. Include the error in your answer.

gradient of best fit $= \frac{y_2 - y_1}{x_2 - x_1} = \frac{23.4 - 2.4}{3150 - 250} = \frac{21}{2900} = 0.00724 = 7.24 \times 10^{-3}$

gradient of worst fit $= \frac{y_2 - y_1}{x_2 - x_1} = \frac{21.8 - 3.6}{2850 - 450} = \frac{18.2}{2400} = 7.58 \times 10^{-3}$

error in gradient = gradient worst fit − gradient best fit
$= 7.583 \times 10^{-3} - 7.24 \times 10^{-3}$
$= 3.43 \times 10^{-4}$

gradient = $7.24 \times 10^{-3} \pm 3.43 \times 10^{-4}$ [2]


LINE OF WORST FIT
(3150, 23.4)
(2850, 21.8)
LINE OF BEST FIT
24
22
20
18
16
14
12
10
8
6
4
2
$d^2$ / $10^{-4}$ m$^2$
(450, 3.6)
(250, 2.4)
0
500
1000
1500
2000
2500
3000
$V$ / V

**(d)** The magnetic flux density $B$ of the magnetic field is $7.9 \times 10^{-3}$ T. Using the answer to **(c)(iii)**, determine the value of $\frac{e}{m}$. Include the error in your value and an appropriate unit.

gradient $= \frac{8m}{B^2 e} = \frac{8}{(7.9 \times 10^{-3})^2} \frac{m}{e}$

$7.24 \times 10^{-3} = 12.82 \times 10^{7} \frac{m}{e}$

$\frac{m}{e} = \frac{7.24 \times 10^{-3}}{12.82 \times 10^{7}}$

$= 5.65 \times 10^{-8}$

$\frac{e}{m} = \frac{1}{5.65 \times 10^{-8}} = 1.77 \times 10^{8}$

$\Delta e/m = \frac{\Delta g \times e/m}{g}$

$= \frac{3.43 \times 10^{-4} \times 1.77 \times 10^{8}}{7.24 \times 10^{-3}}$

$= 8.39 \times 10^{6}$

$\frac{e}{m}$ = $1.77 \times 10^{8} \pm 8.39 \times 10^{6}$ $m^{-1} s^{-2} T^{-2}$ [3]

**(e)** The experiment is repeated with a different magnetic flux density. When $V$ is 500 V, the measured value of $d$ is $(3.8 \pm 0.1) \times 10^{-2}$ m. Using your answer to **(d)**, determine a value for the new magnetic flux density, $B$. Include the error in your value.

$B^2 d^2 e = 8mV$

$B = \sqrt{\frac{8mV}{d^2 e}}$

$= \sqrt{\frac{8 \times (5.65 \times 10^{-8}) \times 500}{(3.8)^2}}$

$= 4.95 \times 10^{-4}$

$\frac{\Delta B}{B}$

$B$ = $4.95 \times 10^{-4} \pm 0.01$ T [2]

Question 2 was generally well answered with the candidate only having difficulty in the last two parts. It was pleasing to see the candidate use clear methods.

The candidate correctly determined an expression for the gradient in terms of $e$, $m$ and $B$. The candidate demonstrates clearly how the answer is determined. It should be noted that just linking $y = mx + c$ would not have gained credit. An explicit statement of gradient is needed.

The basic results table was calculated correctly with an appropriate number of significant figures given. The method of determining the absolute uncertainties was correct in all cases.

The plotting of points and error bars was good; the points were clearly indicated and the ends of the error bars were clearly distinguished. Both the line of best fit and the worst acceptable lines were labelled. The line of best fit and the worst acceptable line were drawn carefully and were correct, the worst acceptable line clearly passing through the top of the top error bar and the bottom of the bottom error bar.

The candidate calculated both the gradient of the line of best fit and the worst acceptable line correctly and thus determined the uncertainty in the gradient correctly from the difference in the two values. The values for the gradient calculation were clear and could be checked easily. The power of ten error when reading off the $y$-axis was not penalised at this stage. The method for determining the uncertainty in the gradient was also clearly demonstrated.

Part **(d)** was correct apart the power of ten error when calculating $e/m$. To determine the uncertainty in $e/m$ the candidate's fractional method was correct; it should be noted that the working was clear. The unit ($m^{-1}\,s^{-2}\,T^{-2}$) is incorrect. The candidate would appear to be trying to use base units but was confused by the term $V$ in the original equation in the question (perhaps thinking that it was a speed). If the unit had been correctly given in base units then credit would have been given. Similarly credit would have been given for $V\,m^{-2}\,T^{-2}$.

In **(e)** the candidate did not gain an answer in the range given and thus did not gain credit. There would appear to be errors in the candidate's calculation. Initially the formula quoted is correct; however, the substitution for $e/m$ is incorrect and the candidate has only substituted 3.8 m for $d$ rather than $3.8 \times 10^{-2}$ m. The candidate makes no attempt to show working to determine the uncertainty in $B$; it is important that candidates clearly indicate how their answers are obtained.

***Candidate E***

Values of *V* and *d* are given in Fig. 2.2.

| *V*/V | *d*/$10^{-2}$m | $d^2$/$10^{-4}$m$^2$ |
|---|---|---|
| 500 | 2.1 ± 0.1 | 4.41 ± 0.42 |
| 1000 | 2.8 ± 0.1 | 7.84 ± 0.56 |
| 1500 | 3.4 ± 0.1 | 11.56 ± 0.68 |
| 2000 | 3.9 ± 0.1 | 15.21 ± 0.78 |
| 2500 | 4.3 ± 0.1 | 18.49 ± 0.86 |
| 3000 | 4.7 ± 0.1 | 22.09 ± 0.94 |

**Fig. 2.2**

It is suggested that *V* and *d* are related by the formula

$$\frac{e}{m} = \frac{8V}{B^2d^2}$$

where *e* is the charge on the electron and *m* is the electron mass.

**(a)** A graph of $d^2$ on the *y*-axis against *V* on the *x*-axis is to be plotted. Write down an expression for the gradient in terms of *e*, *m* and *B*.

$$\frac{e}{m} = \frac{8V}{B^2d^2}$$

$$d^2 = \frac{8mV}{eB^2}$$

$y = mx$

where $m = 8m/eB^2$

gradient = $\frac{8m}{eB^2}$ [1]

**(b)** Calculate and record values of ($d^2$ / $10^{-4}$ m$^2$) in Fig. 2.2. Include in the table the absolute errors in $d^2$. [3]

**(c) (i)** Plot a graph of $d^2$ on the *y*-axis against *V* on the *x*-axis. Include error bars for $d^2$. [2]

**(ii)** Draw the best-fit straight line and a worst acceptable straight line on your graph. Both lines should be clearly labelled. [2]

**(iii)** Determine the gradient of the best-fit line. Include the error in your answer.

points of best line (350, 3.2)
(3200, 23.6)

gradient = $\frac{3200-350}{(23.6-3.2)\times10^{-4}}$

= 139.705 ≈ $1.40\times10^6$

worst line :- (~~3200~~ 3000, 23)
(505, 4)

gradient = $\frac{3000-505}{(23-4)\times10^{-4}}$

= 131.315 ≈ $1.31\times10^6$

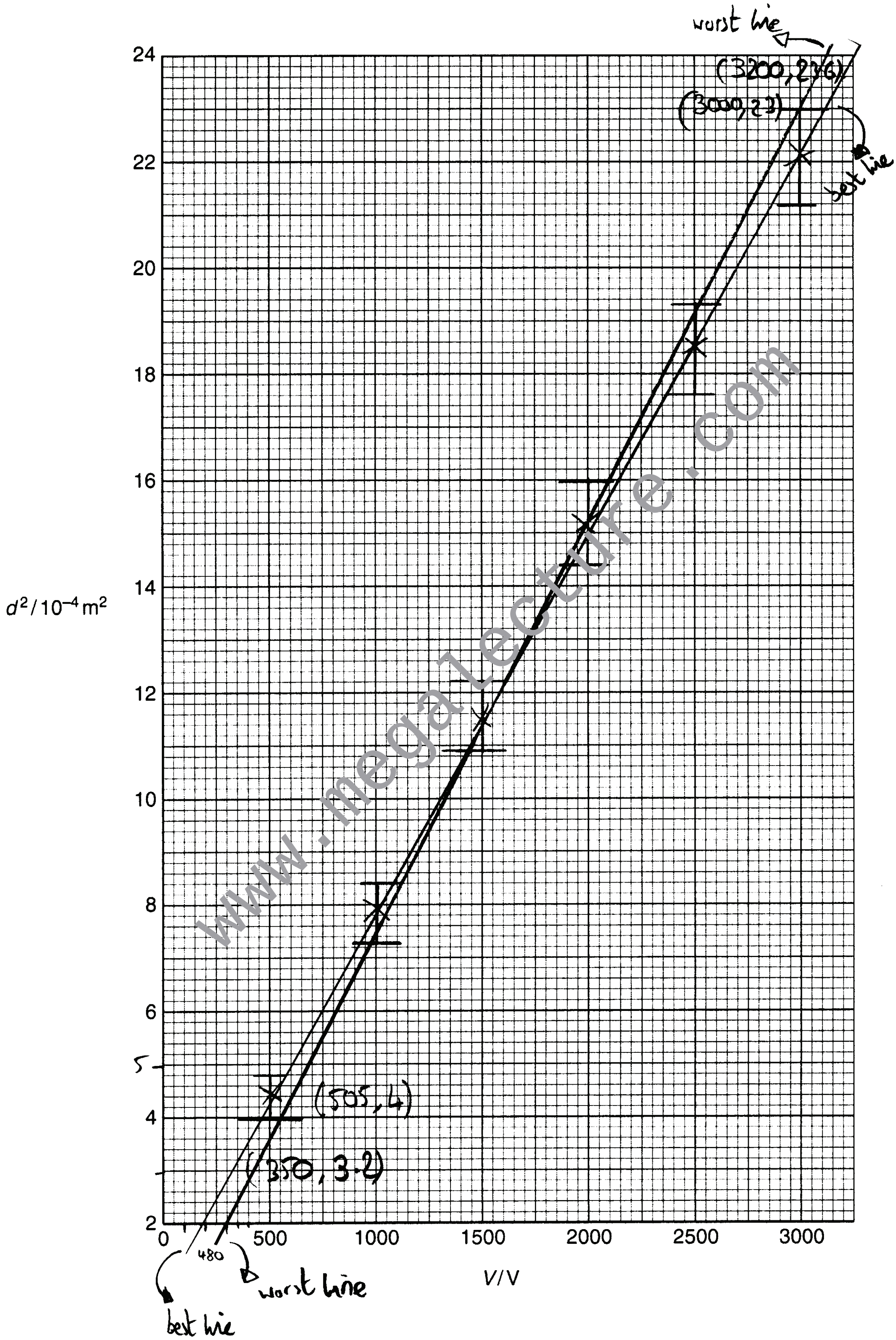
% uncertainty (error) = $\frac{139.705-131.315}{139.705}\times100\%$

= 6.00%

$1.40\times10^6 \pm 6.00\%$

gradient = ~~(140 ± 6.00%)~~ [2]

= $(140 \pm 8.40)\times10^4$


worst line
(3200,23.6)
(3000,23)
best line
$d^2/10^{-4}\,m^2$
24
22
20
18
16
14
12
10
8
6
5
4
2
0
500
1000
1500
2000
2500
3000
(505,4)
(350,3.2)
480
worst line
best line
V/V

**(d)** The magnetic flux density $B$ of the magnetic field is $7.9 \times 10^{-3}$ T. Using the answer to **(c)(iii)**, determine the value of $\frac{e}{m}$. Include the error in your value and an appropriate unit.

~~gradient = $\frac{8M}{B^2d^2e}$~~

~~$140 \pm 6.00\% = 8x$~~

best line = (350, 3.2)

voltage = (500 ± 1)

= (500 ± 0.2%)

$\frac{e}{M} = \frac{8V}{B^2d^2}$

$\frac{e}{M} = \frac{8 \times (500 \pm 0.2\%)}{(7.9 \times 10^{-3})^2 \times (4.2 \times 10^{4} \pm 10\%)}$

$\frac{e}{M} = (1.53 \times 10^{-3} \pm 10.20\%)$

$\frac{e}{m}$ = $(1.53 \times 10^{3} \pm 10.00\%)$ [3]

**(e)** The experiment is repeated with a different magnetic flux density. When $V$ is 500 V, the measured value of $d$ is $(3.8 \pm 0.1) \times 10^{-2}$ m. Using your answer to **(d)**, determine a value for the new magnetic flux density, $B$. Include the error in your value.

$(1.53 \times 10^3 \pm 10.00\%) = \frac{8 \times 500V}{B^2 \times ((3.8 \pm 0.1) \times 10^{-2})^2}$

$1.53 \times 10^3 \pm 10.00\%) = \frac{4000}{B^2 \times (14.44 \pm 0.76) \times 10^{-4}}$

$B^2(1.53 \times 10^3 \pm 10.00\%)(38 \times 10^{-4} \pm 5.26\%) = 4000$

$B = (82.9 \pm 7.63\%)$ T

$B$ = $(8.29 \pm 7.63\%)$ T [2]

Question 2 was generally well answered at the beginning but the candidate found the last parts more challenging.

The candidate correctly determined an expression for the gradient in terms of *e*, *m* and *B*. Again it is pleasing to see the candidate demonstrate the answer clearly. Weaker candidates often do not show their working and as a result often find the algebraic manipulation difficult. Some weaker candidates omitted the '8' from their final expression.

The basic results table was calculated correctly but from row three onwards the candidate has not used an appropriate number of significant figures (sf). Since the raw data is given to 2 sf, then the calculated values of $t^2$ should be given to two or three significant figures. In row three this means that the allowable values would be either 12 (2 sf) or 11.6 (3 sf). Another common mistake that weaker candidates make is to truncate their answers; again using row three, if the candidate had written '11.5', then this would have been penalised. The method of determining the absolute uncertainties was correct in all cases. Significant figures in uncertainties are not penalised in **(b)** and thus ±0.42 and ±0.4 in the first row would both have gained credit.

The plotting of points and error bars was good; the points were clearly indicated and the ends of the error bars were clearly distinguished. Weaker candidates tend to lose one of these marks for careless plotting of points. Candidates should be encouraged to check plots that do not appear to lie on a straight line (or smooth curve). Both the best fit and worst acceptable lines were labelled. The line of best fit was drawn correctly but the worst acceptable line was incorrect, since it did not pass through the bottom of the bottom error bar. Another error that occurs on weaker scripts is where the worst acceptable line is parallel to the line of best fit.

The candidate calculated the gradient of the best fit line and the worst acceptable line incorrectly. The read-offs from the graph were clearly indicated and the candidate also realised that $d^2$ was measured in $10^{-4}$ $m^2$ but the candidate calculated $\Delta x / \Delta y$. The candidate also calculated the gradient of the worst acceptable line by finding $\Delta x / \Delta y$, before calculating the percentage uncertainty in the gradient rather than the absolute uncertainty. In this case, the candidate has demonstrated the method for the determining the percentage uncertainty (by finding the gradient of the worst acceptable line and determining the difference with the previous gradient calculated), and thus credit may be given since the $\Delta x / \Delta y$ has already been penalised in the first part. This is a good example of where an examiner would apply the 'error carried forward' rule.



Part **(d)** was incorrect. The candidate substituted a point from the line rather than the gradient as required by the question (furthermore, the value from the line was incorrectly read). Weak candidates often substitute data points from their table of results rather than using the gradient. Another error by weaker candidates is the incorrect evaluation of the expression, often becoming confused with powers of ten. There is little evidence as to why the candidate has given the uncertainty as 10% – examiners would expect to see a clear method for this mark to be awarded. The unit was omitted – a common occurrence in weaker candidates' scripts. Candidates should be encouraged to try to determine the unit from the information that they have been given. In this case, using the equation given earlier would give a unit of $V\,T^{-2}\,m^{-2}$, which would have gained credit.

There is often one mark available on the paper for correct work throughout the paper and being able to obtain an answer within a specified range. In **(e)** the candidate's response was not within the required range. The uncertainty or percentage uncertainty was not clear and thus did not gain credit. A clear method is essential for the award of this mark.

## Conclusion

**Candidate A**

The candidate has applied good practical physics skills to both Question 1 and Question 2. In Question 1, there was clear evidence of good methods of data collection and the analysis section was logically illustrated.

**Candidate B**

The candidate has applied good practical physics skills to both Question 1 and Question 2. In Question 1, there was evidence of good methods of data collection including a very good diagram. In Question 2, the candidate demonstrates good basic knowledge but does not excel in the final parts with the required accuracy that would be expected of an A grade candidate.

**Candidate E**

The candidate has applied some practical physics skills to both Question 1 and Question 2 and thus deserves a grade at A level. In Question 1, there was some clear evidence of good methods of data collection and the analysis was encouraging, but the candidate did not answer the plan in sufficient detail for the award of a high grade. In Question 2, there is evidence of a reasonable standard of basic skills with a few slips; higher grades would not be accessed because the candidate was unable to deal with the more complicated analysis required in the latter parts.