Cambridge Assessment International Education

Example Responses – Paper 5

Cambridge International AS & A Level Physics 9702

For examination from 2022

Cambridge Pathway

Contents

Introduction

The main aim of this booklet is to exemplify standards for those teaching Cambridge International AS & A Level Physics 9702.

This booklet contains responses to all questions from June 2022 Paper 52, which have been written by a Cambridge examiner. Responses are accompanied by a brief commentary highlighting common errors and misconceptions where they are relevant.

The question papers and mark schemes are available to download from the School Support Hub.

9702 June 2022 Question Paper 52

9702 June 2022 Mark Scheme 52

Past exam resources and other teaching and learning resources are available from the School Support Hub.

Question 1

1 Two parallel cylindrical conductors each have a small cross-sectional area A. A thin metal bar connects the two conductors, as shown in Fig. 1.1.

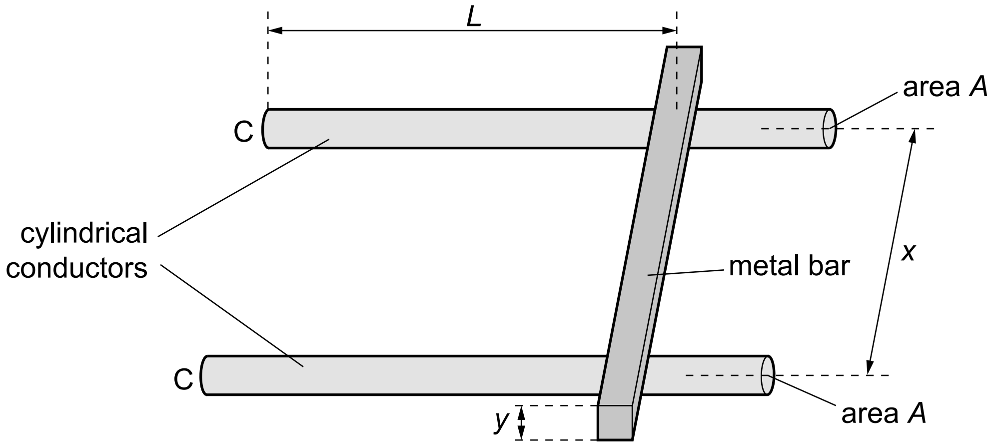


Fig. 1.1 (not to scale)

The metal bar has a square cross-section with sides of length y. For each conductor, the distance between its end C and the centre of the metal bar is L. The distance between the centres of the conductors is x.

The ends C are connected to a power supply and the current I in the conductors is measured.

It is suggested that I is related to L by the relationship

$$\frac{E}{I} = \frac{2PL}{A} + \frac{Qx}{y^2}$$

where E is the electromotive force (e.m.f.) of the power supply, and P and Q are constants.

Plan a laboratory experiment to test the relationship between I and L.

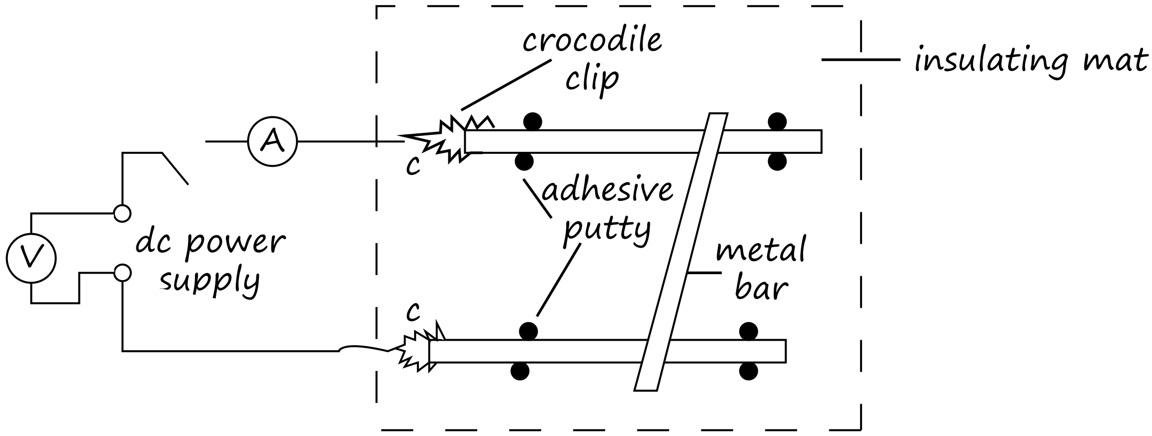
Draw a diagram showing the arrangement of your equipment.

Explain how the results could be used to determine values for P and Q.

In your plan you should include:

- the procedure to be followed
- the measurements to be taken
- the control of variables
- the analysis of the data
- any safety precautions to be taken.

Diagram



Defining the problem

In this experiment I will vary the distance L and measure the current I.

The independent variable is L and the dependent variable is I. To make the experiment a fair test I will keep E, A, x and y constant.

I will set up the apparatus shown in the diagram on an insulating mat on the bench to prevent conduction through the bench.

To measure the e.m.f. E of the power supply I will open the switch and record the voltmeter reading. To measure the distance L, I will use vernier calipers to measure the distance from C to the edge of the metal bar and I will then add y/2 to determine L. This process will be repeated with the other conductor so that L is the same for both conductors.

I will close the switch and record the current I indicated by the ammeter. I will then open the switch.

I will use a metre rule to measure the distance x between the two conductors. This measurement will be repeated at various positions to ensure that x is the same along the length of the conductors. I will measure the distance between the conductors and add the diameter of the conductors. I will use a micrometer to measure both y and the diameter d of the cylindrical conductors. I will repeat the measurements of y along the metal bar and find an average value for y. I will repeat the measurements of d along the cylindrical conductors and find an average. The area of the conductors is calculated by $\pi d^2/4$.

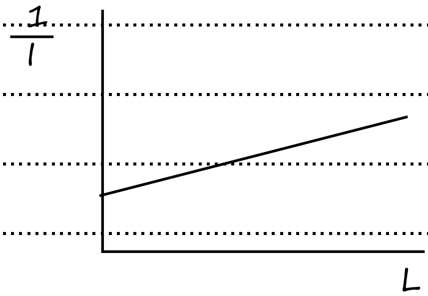
Analysis

Since $\frac{E}{I} = \frac{2PL}{A} + \frac{Q_x}{y^2}$

So $\frac{1}{I} = \frac{2P}{EA}L + \frac{Qx}{Ey^2}$

$y = mx + c$

I will plot a graph of $\frac{1}{I}$ against L.



The relationship would be valid if the graph is a straight line with a y-intercept of $\frac{Qx}{Ey^2}$.

Since gradient $= \frac{2P}{EA}$, $P = \frac{EA}{2} \times$ gradient

and since y-intercept = $\frac{Qx}{Ey^2}$, $Q = \frac{Ey^2}{x} \times$ y-intercept

Safety

Since there are bare conductors, I will switch off the power supply when I change the position of the metal bar so that I do get an electric shock. I will also wear thermal insulated gloves since the metal bar may be hot.

Additional detail

Since the cylindrical conductors may roll, I will place adhesive putty to stop the rolling. I will also use crocodile clips to attach the circuit to the cylindrical conductors.

Examiner comment

- Candidates sometimes did not label their diagrams. Correct circuit symbols needed to be used. Diagrams and circuits should be workable for the experiment set.
- Sometimes candidates suggested other apparatus, for example, an oscilloscope. If they made a suggestion such as this, there should be detail given in the text to indicate how the quantity was determined from the oscilloscope.
- Many candidates often stated that quantities need to be 'controlled', which repeated the wording in the question paper. Candidates should look at the given relationship and identify the quantities that need to be constant to make the experiment a fair test. They needed to state explicitly that these quantities were kept constant.
- The question refers to a thin metal bar. Candidates needed to think of an appropriate measuring instrument to measure a 'thin' distance, so a rule is not the best instrument to use. Candidates should give a definite choice of instrument.
- The question refers to cylindrical conductors with a small cross-sectional area. To determine area, a micrometer or calipers should be suggested to measure the diameter of the cylindrical conductor and then a correct equation that will give the area should be given.
- When discussing repeating results, candidates should be encouraged to explain how the experiment is improved by taking repeats. In this experiment, taking measurements along the length of the conductors or metal bar was needed.
- Good analytical skills include the rearrangement of the given expression into the format of the equation of a straight line. Candidates needed to explicitly identify the quantities that needed to be plotted on the x-axis and the y-axis. It was not enough to just write $y = mx + c$ under the rearranged expression.
- Some candidates stated the expressions that the gradient and y-intercept represent. It was worth checking at this stage that there was a description of how all the quantities in these expressions may be determined. The expressions need to be rearranged so that the constants to be determined from the question were the subject of the equation.
- Many candidates gave general safety rules. They should be encouraged to give reasoned safety precautions which were specific to the experiment. In this experiment, a specific safety precaution could be linked to the metal conductors and/or bar being hot due to the (large) currents.
- Candidates should be encouraged to think of other helpful detail to include. For example, how might the apparatus be prevented from moving during the experiment? How would L be the same on both conductors? How might x be the same along the length of the conductors?

Question 2

2 The brightness of some stars varies regularly. These stars are called variable stars.

Fig. 2.1 shows the variation of luminosity with time for a variable star.

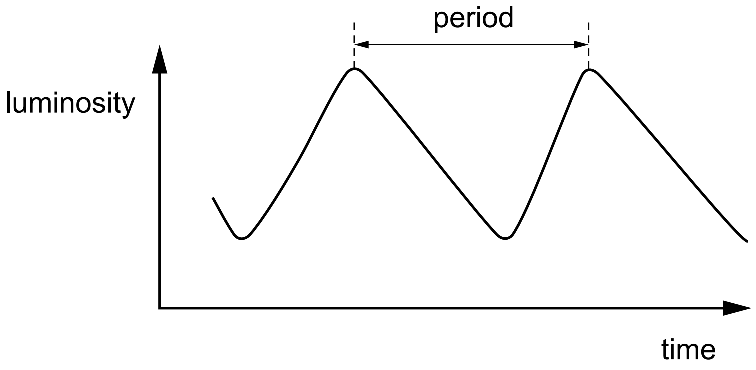


Fig. 2.1

A student determines the period T and mean luminosity L of the star.

The student repeats the process for different variable stars.

It is suggested that L and T are related by the equation

$$L = SKT^a$$

where S is the luminosity of the Sun, and a and K are constants.

(a) A graph is plotted of lg L on the y-axis against lg T on the x-axis.

Determine expressions for the gradient and y-intercept.

Taking logs (to base 10) of both sides of the equation: $\lg L = \lg S + \lg K + a \lg T$

Rearranging into

$y = mx + c$

$\lg L = a \lg T + (\lg S + \lg K)$

gradient = a

y-intercept = $\lg (SK)$

[1]

Examiner comment

- The question indicates the quantities that are plotted on the x-axis and the y-axis. Candidates should use the white space for changing the given expression into the equation of a straight line $y = mx + c$.
- A common misunderstanding was the difference between lg and ln.
- Some candidates gave an alternative for the y-intercept of "(lg S + lg K)" which was awarded marks.

(b) Values of T and L are given in Table 2.1.

Table 2.1

T/days	$L/10^{30}$ W	lg (T/days)	lg ($L/10^{30}$ W)
22	2.9 ± 0.2	1.34	0.46 ± 0.03
32	4.9 ± 0.2	1.51	0.69 ± 0.02
42	6.9 ± 0.2	1.62	0.84 ± 0.01
54	9.8 ± 0.2	1.73	0.99 ± 0.01
78	16 ± 2	1.89	1.20 ± 0.06
97	21 ± 2	1.99	1.32 ± 0.04

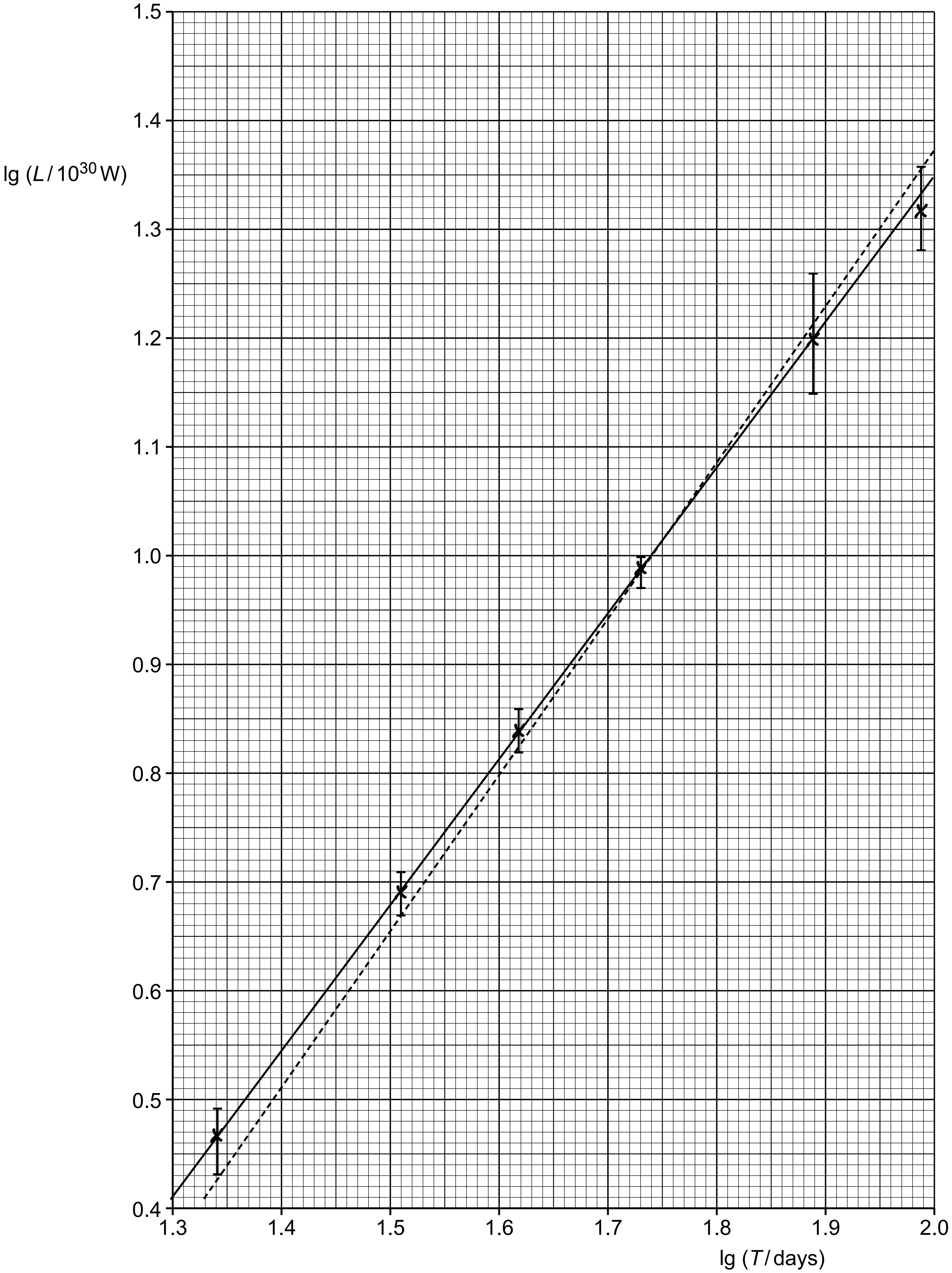
Calculate and record values of lg (T/days) and lg ($L/10^{30}$ W) in Table 2.1.
Include the absolute uncertainties in lg ($L/10^{30}$ W). [2]

Examiner comment

- Some candidates rounded the logarithmic quantities incorrectly. The number of decimal places in the logarithmic quantity should be same (or one more) than the number of significant figures in the quantity. In this question, since data in T / days was given to two significant figures, the calculations of lg (T / days) should have been given to two (or three) decimal places. This rule also applies to the calculations of lg (L / 10^{30} W) – mistakes in this column of data were commonly made in the last two rows. For example, lg (21) was sometimes written as 1.3 where the candidate incorrectly gave the value to two significant figures rather than two decimal places.
- Some candidates incorrectly rounded answers. For example, in the second row of lg (T / days), the answer was sometimes incorrectly written as 1.50. The value of lg (32) was 1.505149978. Some candidates incorrectly rounded this to 1.50 rather than 1.51 or 1.505.
- Some candidates incorrectly used a fractional uncertainty method to determine the uncertainty in lg (T / days). To determine the uncertainty in logarithmic quantities, the following methods would be valid:
  - difference between the maximum value and the actual value
  - difference between the minimum value and the actual value
  - half the difference between the maximum and minimum values.

(c) **(i)** Plot a graph of lg (L / 10^{30} W) against lg (T / days).
Include error bars for lg (L / 10^{30} W). [2]

(ii) Draw the straight line of best fit and a worst acceptable straight line on your graph. Label both lines. [2]



Examiner comment

- **(i)** Some candidates drew large 'blobs'. The centre of the cross should be drawn with a fine pencil, and the diameter of the intersection of the cross needed to be less than half a small square.
- **(i)** Error bars should be plotted for all points. Sometimes, thick error bars were drawn – a fine line should be used to indicate the end of the error bar. The error bars should be symmetrical and accurate to less than half a small square.
- **(ii)** Some candidates thought that lines of best should be drawn from the top point to the bottom point. In this experiment, a line drawn like this would mean that there would be four data points above the line. Candidates should be encouraged to have a balance of plotted points above and below their line. They would find it easier to use a transparent 30 cm ruler – this means that they could see the plotted points through the ruler and will not have a kink in their line. Again, a fine pencil is useful, the thickness of the line should be less than 1 mm.
- **(ii)** The worst acceptable line should be the steepest or shallowest line that passes through all the error bars. In some cases, it may not pass through the extremities of the first and last data plots. In the example response, the worst acceptable line at the bottom was just within the extremity because to pass through all the error bars it was constrained by the second and third error bars from the left.
- **(ii)** If a dashed line was used, the dashes must pass through each error bar. It was also helpful for candidates if the dashes cross gridline intersections as this would help them to choose accurate read-offs for the gradient and *y*-intercept determinations.

(iii) Determine the gradient of the line of best fit. Include the absolute uncertainty in your answer.

$$\text{gradient} = \frac{1.28 - 0.50}{1.95 - 1.37} = 1.345$$

$$\text{gradient of worst acceptable line} = \frac{1.15 - 0.59}{1.84 - 1.45} = 1.436$$

$$\text{uncertainty} = 1.436 - 1.345 = 0.091$$

$$\text{gradient} = 1.345 \pm 0.091$$

Examiner comment

- To determine the gradient, candidates needed to choose two points that were as far apart as possible on the line. A common mistake was to use the data values from the table; these plotted points may not be on the line. It was easier to read off the data points if they were at the intersection of grid lines. Some candidates indicated clearly the data points used on the graph by a dot or a small triangle. Other candidates drew triangles, this was helpful as it ensured that the values read off from the line were the same.
- For the worst acceptable line, it was helpful for the dashed line to pass through the intersection of grid lines.
- Candidates should clearly show the subtraction of the gradient of the line of best fit and the gradient of the worst acceptable line.
- Another common misconception is dealing with powers of ten. Since logarithmic quantities are numbers, the powers of ten in this experiment are not used at this stage.

(iv) Determine the *y*-intercept of the line of best fit. Include the absolute uncertainty in your answer.

$y\text{-intercept} = 1.28 - 1.345 \times 1.95 = -1.343$

$y\text{-intercept} = 1.15 - 1.436 \times 1.84 = -1.492$

$\text{uncertainty} = -1.343 - -1.492 = 0.149$

$y\text{-intercept} = -1.343 \pm 0.149$

y-intercept = -1.343 ± 0.149 [2]

Examiner comment

- There were many common errors in determining the y-intercept. Many candidates incorrectly read off the value from the y-axis without realising that *x* was not zero so there was a false origin. Candidates needed to use the gradient and substitute a point from the line into *y* = *mx* + *c*. A data point from the gradient calculation could be used.
- Other common errors include determining the y-intercept from *y*/*mx* or *mx* – *y*.
- Common errors for determining the y-intercept of the worst acceptable line included using the gradient of the line of best fit or a point that was on the line of best fit. It was helpful to use one of the data points used in the calculation of the gradient of the worst acceptable line.
- Candidates needed to clearly show the subtraction of the *y*-intercept of the line of best fit and the *y*-intercept of the worst acceptable line.

(d) Using your answers to **(a)**, **(c)(iii)** and **(c)(iv)**, determine the values of *a* and *K*. Include the absolute uncertainties in your values. You need not be concerned with units.

Data: $S = 3.85 \times 10^{26}$ W

$SK = 10^{y\text{-intercept}}$

gradient = a

$y\text{-intercept} = \lg(SK)$

$$K = \frac{10^{-1.343}}{3.85 \times 10^{26}} \times 10^{30} = 118$$

$$\text{worst acceptable } K = \frac{10^{-1.492}}{3.85 \times 10^{26}} \times 10^{30} = 83.7$$

$\text{uncertainty in } K = 118 - 84 = 34$

a = 1.35 ± 0.091

K = 118 ± 34

[3]

Examiner comment

- Candidates found it helpful to show clearly the substitution of the gradient and *y*-intercept into the expressions determined in **(a)**.
- Many candidates did not consider the number of significant figures in quantities determined. In this experiment, the data for *T* and *L* were given to two significant figures, *a* and *K* should be given to two or three significant figures.
- A common confusion observed in this part was using the exponential function. The exponential function should be used for natural logarithms.
- Candidates were often unsure how to deal with the powers of ten. Many gave an answer for *K* of 1.18×10^{-28} that did not allow for the 10^{30}.
- A common misconception was to determine the uncertainty in *K* by a fractional uncertainty method using the *y*-intercept. To determine the uncertainty, the worst acceptable *y*-intercept should be substituted into the expression to determine a value for *K* from the worst acceptable line.

(e) A variable star has a period of 5.0 days.

Determine the luminosity L of this star.

$L = 3.85 \times 10^{26} \times 118 \times 5.0^{1.35}$

$L = 3.989810 \times 10^{29}$ (W) $= 4.0 \times 10^{29}$ (W)

L = 4.0×10^{29} W [1]

[Total: 15]

Examiner comment

- Candidates were often unsure how to deal with the powers of ten. Many gave an answer of about 0.4 W because they did not realise that their equation would provide a luminosity in 'units' of 10^{30} W. Some candidates realised the error and tried to add in factors of 10^{26} (from the Sun) or 10^{28}.
- There was an equally correct alternative method:

  $\lg L = 1.35 \times \lg 5.0 + -1.343 = -0.399$

  $L = 10^{-0.399} \times 1030 = 3.990 \times 10^{29}$ (W) $= 4.0 \times 10^{29}$ (W)
- Candidates needed to clearly show the substitution of the data and give the answer to an appropriate number of significant figures.
- A common error was to change the five days into seconds. This was incorrect since the relationship directly used the time in days. Candidates needed to ensure that the units used were consistent.

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