

Please write clearly in block capitals.

Centre number

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Candidate number

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Surname StemUp Model Solution

Forename(s) _____

Candidate signature _____

I declare this is my own work.

INTERNATIONAL A-LEVEL PHYSICS

Unit 5 Physics in practice

Thursday 18 January 2024

07:00 GMT

Time allowed: 2 hours

Materials

For this paper you must have:

- a Data and Formulae Booklet as a loose insert
- a ruler with millimetre measurements
- a scientific calculator, which you are expected to use where appropriate
- a protractor.

Instructions

- Use black ink or black ball-point pen.
- Fill in the boxes at the top of this page.
- Answer **all** questions.
- You must answer the questions in the spaces provided. Do not write outside the box around each question or on blank pages.
- All working must be shown.
- If you need extra space for your answer(s), use the lined pages at the end of this book. Write the question number against your answer(s).
- Do all rough work in this book. Cross through any work you do not want to be marked.

Information

- The marks for questions are shown in brackets.
- The maximum mark for this paper is 80.

For Examiner's Use	
Question	Mark
1	
2	
3	
4	
5	
6	
7	
8	
TOTAL	



Section A

Answer **all** questions in this section.

0 1 . 1

Describe how to reduce the effect of random errors on a set of measurements.

[1 mark]

Repeat each measurement several times and calculate the mean, ignoring any anomalous readings.

A student measures the length l of a simple pendulum six times using a metre ruler.

Table 1 shows her measurements.

Table 1

l / cm	89.4	89.3	89.5	89.4	89.4	89.5
-----------------	------	------	------	------	------	------

0 1 . 2

Calculate the mean value of l .

[1 mark]

$$\begin{aligned} \text{mean} &= (89.4 + 89.3 + 89.5 + 89.4 + 89.4 + 89.5) / 6 \\ &= 536.5 / 6 = 89.42 \text{ cm} \end{aligned}$$

mean value of l = 89.4 cm

The student makes repeated measurements of the time for ten oscillations of the simple pendulum.

She calculates that the mean period for one oscillation is $1.95 \text{ s} \pm 1\%$.

0 1 . 3

Comment on whether the student's measurements of time are precise.

[1 mark]

Yes, they are precise: the percentage uncertainty is only 1%, so the repeated readings lie within a small range of values, close to the mean.



The student uses her measurements to determine a value for g .

0 1 . 4

Deduce whether the student's measurements are accurate.

[2 marks]

$$T = 2\pi\sqrt{l/g} \text{ so } g = 4\pi^2 l / T^2 = 4\pi^2 \times 0.894 / 1.95^2 = 9.28 \text{ m s}^{-2}$$

$$\text{uncertainty in } g = 0.1\% + 2 \times 1\% = 2.1\%, \text{ 2.1\% of } 9.28 = 0.2 \text{ m s}^{-2}$$

$$\text{so } g = 9.28 \pm 0.2 \text{ m s}^{-2}, \text{ a range of } 9.08 \text{ to } 9.48 \text{ m s}^{-2}$$

Not accurate: the accepted value 9.81 m s^{-2} lies outside the range 9.08 to 9.48 m s^{-2} , and 9.28 is about 5% below 9.81, which is far from the accepted value.

0 1 . 5

The percentage uncertainty in l is 0.1%.

Another student suggests that there is a systematic error in some of the data.

Discuss the evidence for this suggestion.

[1 mark]

The percentage difference from 9.81 is about 5.4%, much larger than the 2.1% uncertainty in g ($9.28 + 0.2 = 9.48 < 9.81$), so random error cannot explain it: evidence of a systematic error.

6

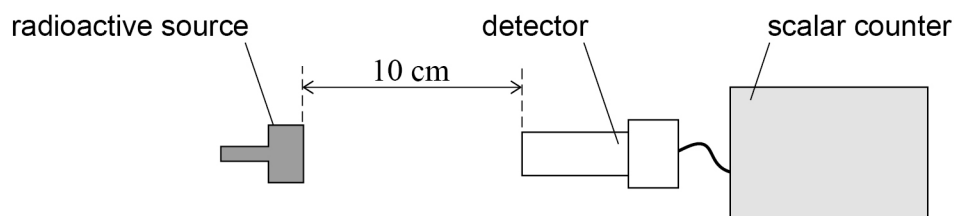
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0 2

Two students **A** and **B** used the apparatus shown in **Figure 1** to determine the count rate from radioactive sources. The activities of the sources did not vary during the determination.

Figure 1

Both students used the same apparatus and placed the detector 10 cm from the source. Each student measured the radioactive count for a time t .

Table 2 shows the measurements made by the two students.

Table 2

	Count	t / s
student A	464	60 ± 1
student B	2150	300 ± 1

When a count is measured as N , the absolute uncertainty in the measurement is $\sqrt{N}$.

Each student calculated the count rate C using the equation:

$$C = \frac{N}{t}$$

The uncertainty in the measurement of the separation of the source and the detector is negligible.



0 2 . 1

State **two** reasons why student **A**'s determination of C has a greater percentage uncertainty than student **B**'s determination of C .

[2 marks]

1 *Student A recorded a smaller count. The percentage uncertainty in a count is $\sqrt{N} / N = 1/\sqrt{N} \times 100\%$, which is larger for smaller N (4.6% for A, 2.2% for B).*

2 *A timed for a shorter period with the same absolute uncertainty of ± 1 s, so A has a larger percentage timing uncertainty (1.7% for A, 0.3% for B).*

0 2 . 2

Deduce, by considering uncertainties, whether the data suggest that both students used the same radioactive source in their determinations of C .

[5 marks]

A: timing: $1/60 \times 100 = 1.7\%$, count: $\sqrt{464} / 464 \times 100 = 4.6\%$

B: timing: $1/300 \times 100 = 0.3\%$, count: $\sqrt{2150} / 2150 \times 100 = 2.2\%$

A: $C = 464 / 60 = 7.7 \text{ counts s}^{-1}$

B: $C = 2150 / 300 = 7.2 \text{ counts s}^{-1}$

A: % uncertainty in $C = 1.7 + 4.6 = 6.3\%$, $\pm 0.49 \text{ counts s}^{-1}$

B: % uncertainty in $C = 0.3 + 2.2 = 2.5\%$, $\pm 0.18 \text{ counts s}^{-1}$

range for A = 7.2 to 8.2 counts s^{-1}

range for B = 7.0 to 7.4 counts s^{-1}

The ranges overlap (7.2 to 7.4 counts s^{-1}), so the data suggest they could have used the same source.

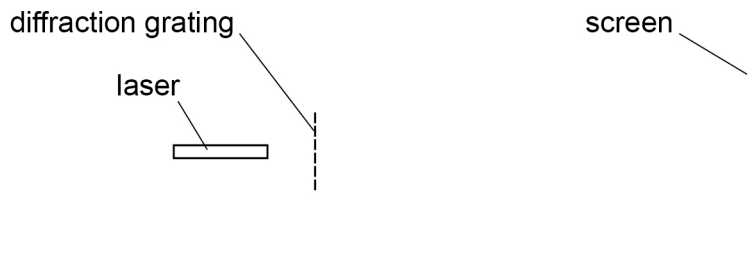
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0 3

Figure 2 shows apparatus used to determine the number of lines per millimetre on a plane transmission diffraction grating. The laser emits light of wavelength 633 nm.

Figure 2



Describe an experiment to determine the number of lines per millimetre on the grating. Refer to the equipment in **Figure 2** and any other necessary equipment.

In your answer you should:

- state the measurements to be made and the steps taken to ensure that the measurements are taken safely
- describe how to process the results
- describe how the experiment should be carried out to ensure accuracy.

[6 marks]

Measurements and safety: set up the laser, grating and screen so the beam is normal to the grating. Use a metre ruler to measure the distance D from the grating to the screen, and the distance x from the zero-order maximum to the first or second-order maximum. Do not look directly into the laser beam, do not point it at anyone, and use a matt screen so there are no reflections.

Processing: calculate the angle θ using $\tan \theta = x / D$, then use $d \sin \theta = n\lambda$ with $\lambda = 633 \text{ nm} = 6.33 \times 10^{-7} \text{ m}$ to find the slit spacing $d = n\lambda / \sin \theta$ in m. The number of lines per mm = $1 / (1000 d)$.

Accuracy: measure the distance $2x$ between the maxima of the same order on either side of the zero order, so that $x = 2x / 2$ (halves the uncertainty). Use a higher order maximum (larger θ , smaller percentage uncertainty) and a large D of about 1 m. Repeat for several orders and repeat the measurements and average.



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0 4

Figure 3 shows apparatus used to investigate how the current I in a battery varies with the length l of resistance wire connected across its terminals. The battery has an emf $\mathcal{E}$ of 3.0 V and an internal resistance r .

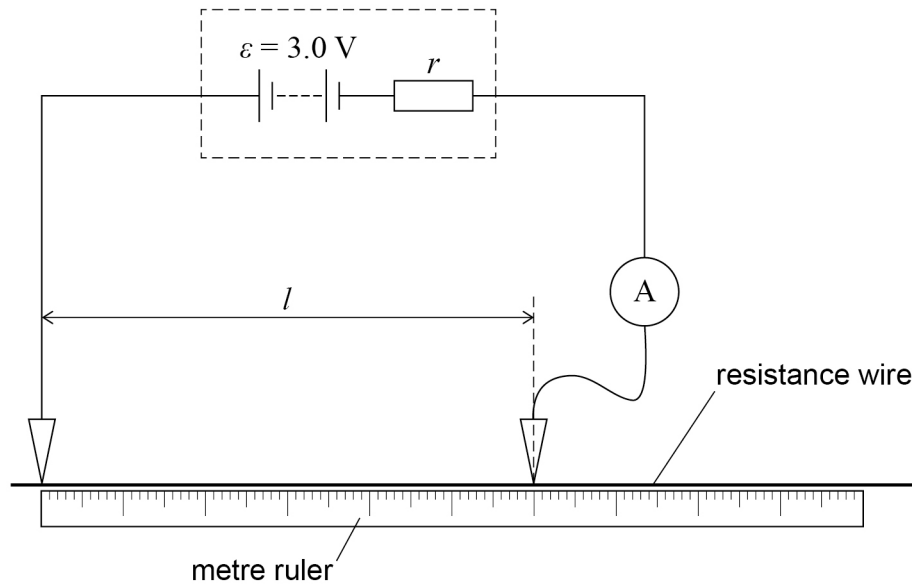
Figure 3

Table 3 shows values of l , I and I^{-1} .

Table 3

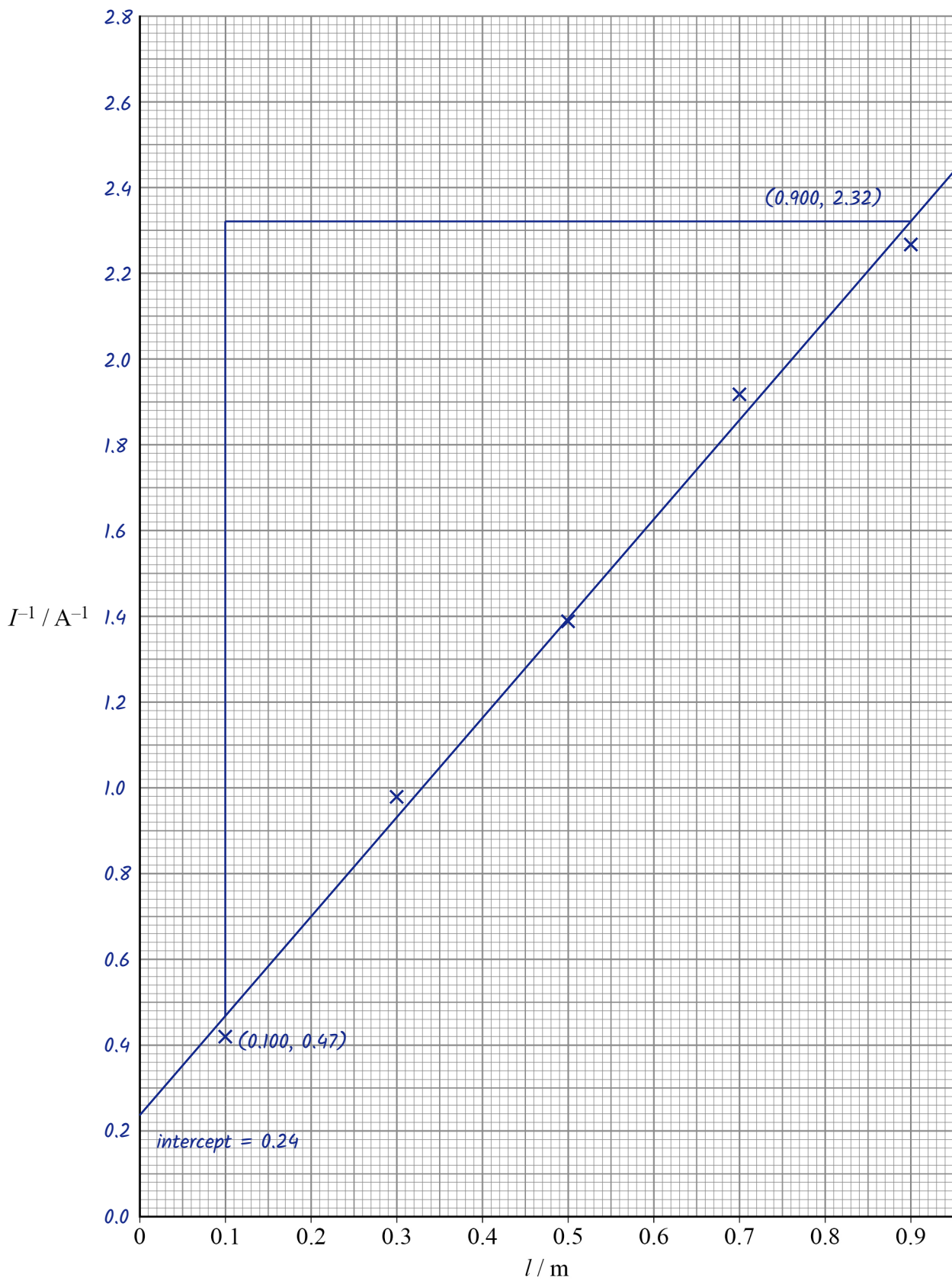
l / m	I / A	I^{-1} / A^{-1}
0.100	2.38	0.42
0.300	1.02	0.98
0.500	0.72	1.39
0.700	0.52	1.92
0.900	0.44	2.27

0 4 . 1

Draw, on **Figure 4**, a graph to show the variation of I^{-1} with l . Draw a best-fit line.

[4 marks]

Figure 4



Question 4 continues on the next page

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0 4 . 2

Determine the gradient of the graph that you have drawn in **Figure 4**.**[2 marks]***from the large triangle: (0.100, 0.47) and (0.900, 2.32)*

gradient = (2.32 - 0.47) / (0.900 - 0.100) = 1.85 / 0.800

gradient = 2.32 A⁻¹ m⁻¹

 R is the resistance of a length l of the wire.The equation that relates I to R is:

$$\frac{1}{I} = \frac{R}{\epsilon} + \frac{r}{\epsilon}$$

0 4 . 3

The resistance wire has a diameter of 0.457 mm.

Calculate, using your answer to Question **04.2**, the resistivity of the material in the resistance wire.**[3 marks]**

$1/I = R/\epsilon + r/\epsilon$ and $R = \rho l / A$, so gradient = $\rho / (\epsilon A)$

$A = \pi d^2 / 4 = \pi \times (0.457 \times 10^{-3})^2 / 4 = 1.64 \times 10^{-7} \text{ m}^2$

$\rho = \text{gradient} \times \epsilon \times A = 2.32 \times 3.0 \times 1.64 \times 10^{-7}$

resistivity = 1.14×10^{-6} $\Omega \text{ m}$

0 4 . 4

Calculate r using data from your graph in **Figure 4**.**[2 marks]**

intercept on the $1/I$ axis = $r/\epsilon = 0.24 \text{ A}^{-1}$

$r = 0.24 \times 3.0$

$r =$ 0.71 Ω

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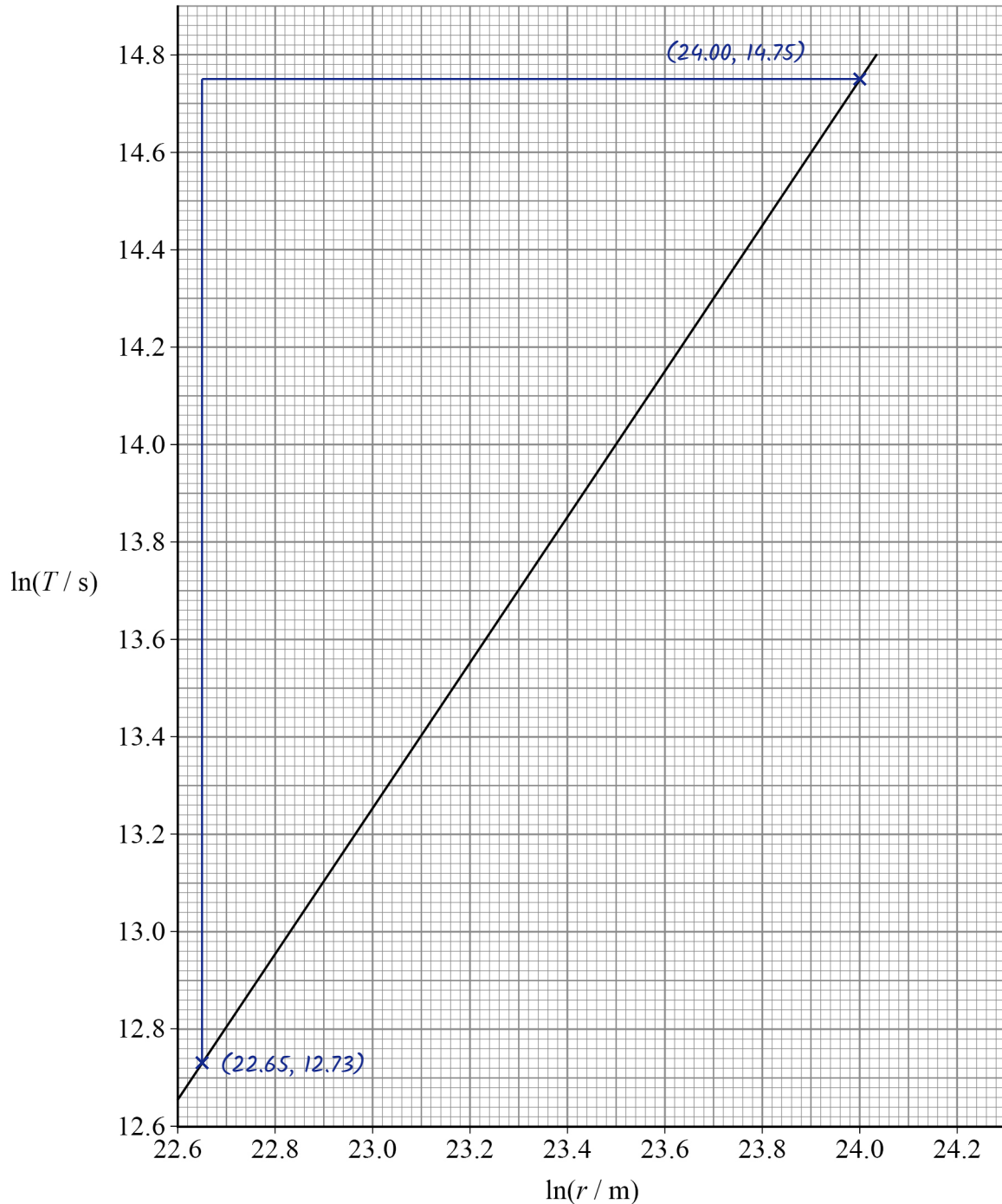


0 5

Astronomers have measured the orbital period T and the orbital radius r for five planets in the solar system of the star HD 108236.

Figure 5 shows the variation of $\ln(T / \text{s})$ with $\ln(r / \text{m})$ for the astronomers' data.

Figure 5



Theory suggests that the relationship between T and r is:

$$T^2 = \frac{4\pi^2 r^3}{GM}$$

where M is the mass of the star HD 108236.



- 0 5 . 1** Show that the intercept c on a graph of $\ln(T / \text{s})$ against $\ln(r / \text{m})$ is given by:

$$c = \frac{1}{2} \ln \left(\frac{4\pi^2}{GM} \right)$$

[2 marks]

$T^2 = 4\pi^2 r^3 / GM$ take natural logs of both sides:

$$2 \ln T = \ln(4\pi^2/GM) + 3 \ln r$$

$$\ln T = (3/2) \ln r + (1/2) \ln(4\pi^2/GM)$$

compare with $y = mx + c$: $y = \ln T$, $x = \ln r$, gradient = $3/2$

so the intercept $c = (1/2) \ln(4\pi^2/GM)$

- 0 5 . 2** Explain, without calculation, how the gradient of the graph in **Figure 5** can be used to show that the astronomers' data are consistent with the relationship on page 12.

[1 mark]

Determine the gradient of the line from a large triangle and compare it with the theoretical value of $3/2 = 1.5$: if they are equal the data are consistent.

- 0 5 . 3** Determine M .

[3 marks]

$$\text{gradient} = (14.75 - 12.73) / (24.00 - 22.65) = 2.02 / 1.35 = 1.496$$

$$\text{using } (24.00, 14.75): c = \ln T - m \ln r = 14.75 - 1.496 \times 24.00$$

$$c = -21.15$$

$$4\pi^2/GM = e^{2c} = e^{-42.31} = 4.26 \times 10^{-19}$$

$$M = 4\pi^2 / (G \times 4.26 \times 10^{-19})$$

$$= 39.48 / (6.67 \times 10^{-11} \times 4.26 \times 10^{-19})$$

$$M = 1.4 \times 10^{30} \text{ kg}$$

6

END OF SECTION A

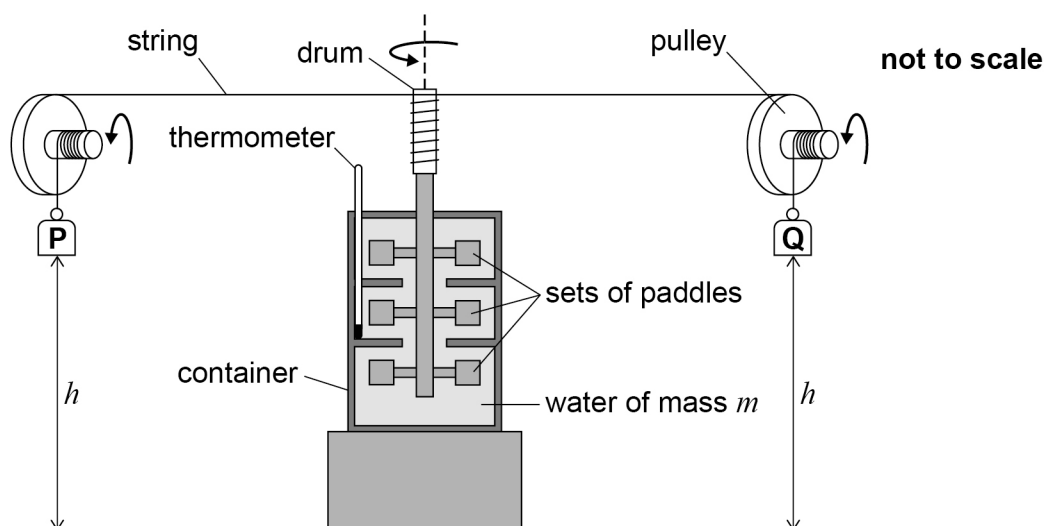
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Section B

Answer **all** questions in this section.**0 6**

Figure 6 shows the apparatus used by Joule to measure the effect of doing work and to determine the specific heat capacity of water.

Figure 6

P and **Q** are masses each of mass M . They fall from rest from an initial height h above the ground. They are connected to a pulley system that turns sets of paddles. The paddles do work by stirring the water in the container.

The gravitational potential energies of **P** and **Q** are transferred to the water. The temperature of the water increases as a result of the work done as **P** and **Q** fall.

When **P** and **Q** reach the ground, the apparatus is reset as in **Figure 6** without causing the paddles to turn. **P** and **Q** are allowed to fall a total of 20 times.

The data collected are:

$$\begin{aligned} h &= 1.5963 \text{ m} \\ M &= 13.158 \text{ kg} \\ m &= 6.2512 \text{ kg} \\ \Delta\theta &= 0.364 \text{ K} \end{aligned}$$

where $\Delta\theta$ is the total increase in temperature of the water and m is the mass of the water.



0 6 . 1

The initial temperature of the water in the container is lower than the temperature of the surroundings.

Explain, with reference to the first law of thermodynamics, why the temperature of the water increases during this experiment.

[3 marks]

First law: $\Delta U = Q + W$, where Q is the energy transferred to the water by heating and W is the work done on the water.

Work is done on the water by the paddle wheels (from the falling masses), and because the water is colder than the surroundings it is also heated by the surroundings, so both Q and W are positive.

So the internal energy U of the water increases, and the increase in internal energy (kinetic energy of its molecules) is seen as a rise in temperature.

0 6 . 2

Show that the total energy transferred by **P** and **Q** as they fall is approximately 8240 J. **[2 marks]**

$$\Delta E_p = Mgh \text{ for each mass, 2 masses, 20 falls}$$

$$\text{total} = 2 \times 20 \times 13.158 \times 9.81 \times 1.5963$$

$$= 8242 \text{ J} \approx 8240 \text{ J}$$

0 6 . 3

State and explain the appropriate number of significant figures that should be given in the answer to Question **06.2**.

[1 mark]

3 significant figures, because g is only given to 3 sf, the data with the fewest sf.

Question 6 continues on the next page

Turn over ►



After each release, **P** and **Q** accelerate briefly before falling at a constant speed of 6.15 cm s^{-1} until they hit the ground.

0 6 . 4

Explain, in terms of the forces acting on the paddles, why **P** and **Q** accelerate briefly before falling at constant speed.

[2 marks]

When released the paddles move slowly, so the drag forces of the water on the paddles are negligible and the resultant force on P and Q is about equal to their weight, so they accelerate.

The resistive (drag) forces increase as the paddles move faster, until the resistive forces are equal and opposite to the weight: the resultant force is zero, so P and Q fall at constant speed.

0 6 . 5

Calculate the total kinetic energy of **P** and **Q** before they hit the ground.

[1 mark]

$$E_k = 1/2 (2M) v^2 = 1/2 \times 2 \times 13.158 \times 0.0615^2$$

$$= 0.0498 \text{ J}$$

total kinetic energy = 0.050 J

0 6 . 6

Explain whether the work done on the water by **P** and **Q** is significantly affected by the total kinetic energy of **P** and **Q**.

[2 marks]

$$\Delta E_p = \text{work done on water} + \Delta E_k \text{ of the masses}$$

$$\text{total } \Delta E_k \text{ for 20 falls} = 20 \times 0.050 = 1.0 \text{ J}$$

$$1.0 \text{ J} / 8240 \text{ J} \approx 0.01\%$$

No: the kinetic energy (1.0 J) is negligible compared with the 8240 J of work done on the water, so it does not significantly affect the result.



0 6 . 7

The total energy transferred by **P** and **Q** as they fall is approximately 8240 J.

$$\Delta\theta = 0.364 \text{ K}$$

$$m = 6.2512 \text{ kg}$$

Joule estimated that:

- 360 J was used to increase the temperature of the container and the paddles
- 0.060 K of the total increase in temperature of the water was caused by thermal conduction from the surroundings.

Calculate a value for the specific heat capacity of water.

[3 marks]

$$\text{energy given to water} = 8240 - 360 = 7880 \text{ J}$$

$$\text{temperature rise caused by work} = 0.364 - 0.060 = 0.304 \text{ K}$$

$$Q = mc\Delta\theta \text{ so } c = Q / m\Delta\theta$$

$$c = 7880 / (6.2512 \times 0.304)$$

$$= 4147 \text{ J kg}^{-1} \text{ K}^{-1}$$

specific heat capacity = 4150 J kg⁻¹ K⁻¹

Question 6 continues on the next page

Turn over ►



Figure 7 shows the diameters of the pulleys and the drum. The pulleys are frictionless. The container and the water have been omitted from **Figure 7**.

P and **Q** each has a mass M of 13.158 kg and produce tensions in their strings of T_P and T_Q respectively.

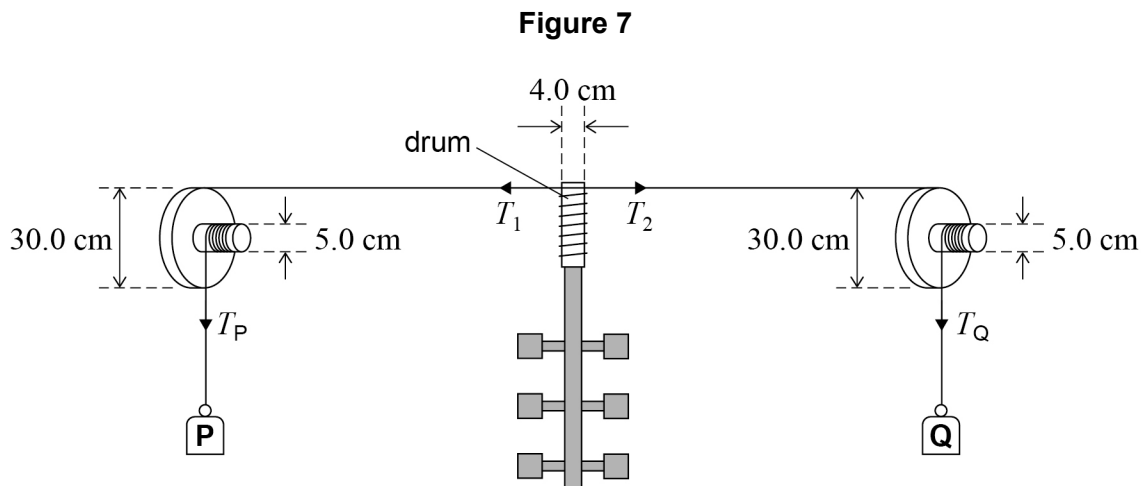
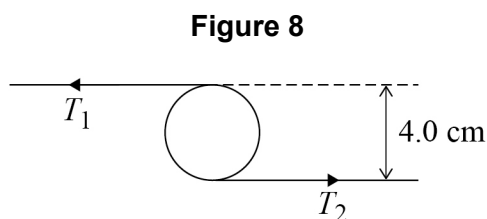


Figure 8 shows the strings and the drum viewed from above. These strings have tensions of T_1 and T_2 that together exert a couple on the drum.



0 6 . 8 **P** and **Q** fall at a constant speed.

Show that the torque applied to the drum by the couple is approximately 0.9 N m.

[3 marks]

$$T_P = Mg = 13.158 \times 9.81 = 129.1 \text{ N}$$

pulley: T_P acts at radius 2.5 cm, T_1 at radius 15.0 cm

$$\text{moments: } T_1 \times 0.150 = T_P \times 0.025 \text{ so } T_1 = 129.1 \times 5/30 = 21.5 \text{ N}$$

$$\text{torque of couple} = T_1 \times \text{separation} = 21.5 \times 0.040$$

$$= 0.861 \text{ N m} \approx 0.9 \text{ N m}$$



0 6 . 9

P and **Q** fall through height h a total of 20 times in 519 s.The total work done on the drum by T_1 and T_2 during this time is 8240 J.

Calculate the angular velocity of the drum.

[2 marks]

$$\text{power} = \text{work} / \text{time} = 8240 / 519 = 15.9 \text{ W}$$

$$\text{power} = \text{torque} \times \omega \text{ so } \omega = 15.9 / 0.861$$

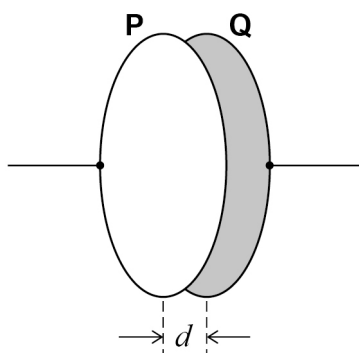
angular velocity = 18.4 rad s⁻¹

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07

Figure 9 shows a capacitor **C** with wires attached to its two circular conducting plates **P** and **Q**. The plates are separated by an air gap of width d .

Figure 9

P and **Q** each has a radius of 1.3 cm. The capacitance of **C** is 52 pF.

07.1

Show that d is approximately 9.0×10^{-5} m.

[2 marks]

$$C = A\epsilon_0 / d \quad \text{so} \quad d = A\epsilon_0 / C$$

$$A = \pi r^2 = \pi \times (1.3 \times 10^{-2})^2 = 5.31 \times 10^{-4} \text{ m}^2$$

$$d = 5.31 \times 10^{-4} \times 8.85 \times 10^{-12} / 52 \times 10^{-12}$$

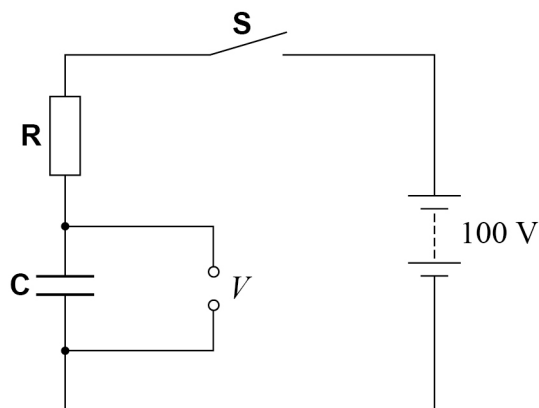
$$= 9.04 \times 10^{-5} \text{ m} \approx 9.0 \times 10^{-5} \text{ m}$$



Figure 10 shows **C** connected in a circuit with a resistor **R**, a switch **S** and a battery. The battery has an emf of 100 V and negligible internal resistance.

R has a resistance of $820 \text{ G}\Omega$.

Figure 10



0 7 . 2

C is initially uncharged.
S is then closed.

After a time t , the voltage V across **C** is 99.2 V.

Calculate t .

[2 marks]

$$V = V_0(1 - e^{-t/RC})$$

$$RC = 820 \times 10^9 \times 52 \times 10^{-12} = 42.6 \text{ s}$$

$$e^{-t/RC} = 1 - 99.2/100 = 0.008$$

$$t = -RC \ln(0.008) = 42.6 \times 4.83$$

$$t = \underline{206} \text{ s}$$

Question 7 continues on the next page

Turn over ►



S remains closed and **C** becomes fully charged.

C is now used as a microphone.

A sound wave of frequency 100 Hz arrives at plate **P**. This causes **P** to oscillate while **Q** does not move.

P oscillates with simple harmonic motion at a frequency of 100 Hz and with an amplitude of 4.5×10^{-6} m.

The width of the air gap repeatedly increases and decreases.

0 7 . 3

Explain why the charge on **C** stays approximately constant as **P** oscillates.

[2 marks]

The resistance of R in series with C is very high ($820 \text{ G}\Omega$), so the time constant $RC = 43 \text{ s}$ is very large compared with the period of the oscillation (0.01 s).

So the current is very small and the charge that can flow onto or off C in the time of one oscillation is negligible: Q stays approximately constant.

0 7 . 4

The width of the air gap decreases by 4.5×10^{-6} m compared with its value in Question 07.1.

Deduce the effect of this change on V .

[3 marks]

$$\text{new } d = 9.04 \times 10^{-5} - 0.45 \times 10^{-5} = 8.59 \times 10^{-5} \text{ m}$$

$$C \propto 1/d, \text{ so } C \text{ increases by } 9.04/8.59 = 1.05 \text{ (about 5\%)}$$

$$Q \text{ constant and } V = Q/C: V = 100 \times 8.59/9.04 = 95 \text{ V}$$

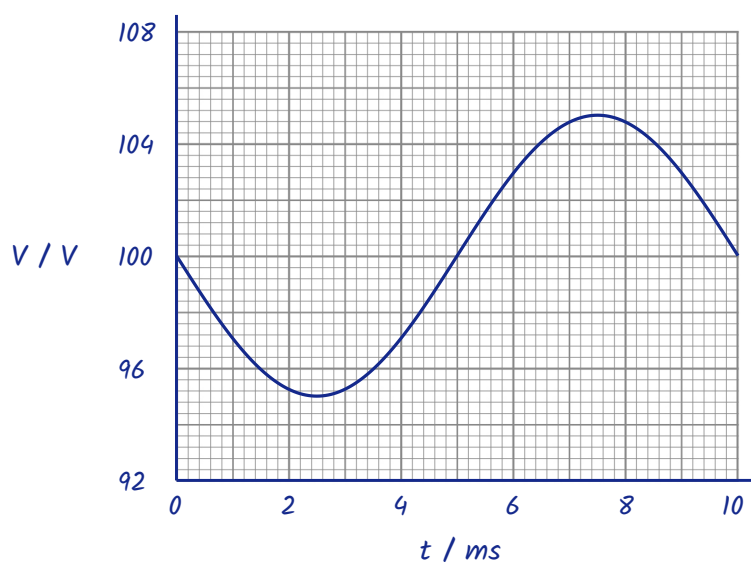
The capacitance increases because d decreases. With Q constant, $Q=CV$ means the pd V decreases, from 100 V to about 95 V (a 5% decrease, because C increases by about 5%).



0 7 . 5

The sound wave arrives at **P** at time $t = 0$ At $t = 0$, $V = 100 \text{ V}$ and **P** begins to move towards **Q**.

Draw, on **Figure 11**, a graph to show the variation of V with t for **one** oscillation of **P**.
Add axes and scales to your graph.

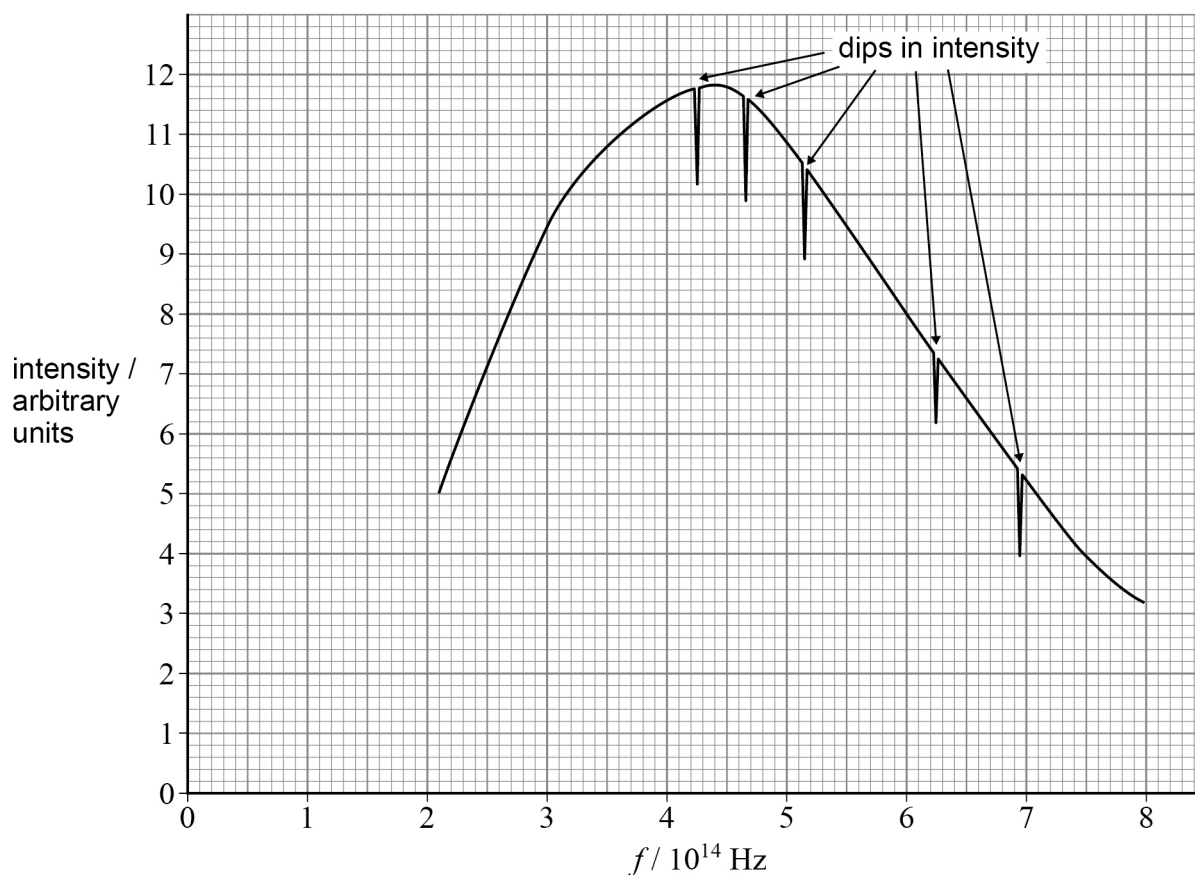
[3 marks]**Figure 11**

12

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0 8

Figure 12 shows how the intensity of the radiation observed on Earth from a star varies with the frequency f of the radiation.

Figure 12

λ_{peak} is the wavelength, in m, of the peak intensity of the radiation emitted from the surface of a star.

λ_{peak} is related to the surface temperature T , in K, of the star by:

$$\lambda_{\text{peak}} = \frac{2.90 \times 10^{-3}}{T}$$

0 8 . 1

Calculate T .

[2 marks]

$$\text{peak at } f = 4.4 \times 10^{14} \text{ Hz}$$

$$\lambda = c/f = 3.00 \times 10^8 / 4.4 \times 10^{14} = 6.82 \times 10^{-7} \text{ m}$$

$$T = 2.90 \times 10^{-3} / \lambda = 2.90 \times 10^{-3} / 6.82 \times 10^{-7} = 4250 \text{ K}$$

$$T = \underline{4300} \text{ K}$$



Question 8 continues on the next page

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0 8 . 2

White light is emitted from the interior of the star. Atoms in the star's outer layers absorb photons of certain frequencies. This causes the dips in intensity in **Figure 12**. The atoms in the outer layers are excited when they absorb the photons.

Explain why the photon frequencies at which the dips occur depend on the particular elements present in the outer layers of the star.

[2 marks]

A photon is absorbed only if its energy hf is exactly equal to the difference between two energy levels in the atom, so the dips show the changes of energy level, and $f = \Delta E/h$.

The energy levels (and so the photon energies) are characteristic of the atoms of each element, so each element absorbs its own set of frequencies.

Antares is a star system that is 550 light years from the Earth. A light year is the distance travelled by light in one year.

Antares emits 7.59×10^4 times as much energy per second as the Sun.

0 8 . 3

Show that one light year is approximately equivalent to 9.5×10^{15} m.

[1 mark]

$$\begin{aligned} 1 \text{ ly} &= c \times 1 \text{ year} = 3.00 \times 10^8 \times 365 \times 24 \times 3600 \\ &= 9.46 \times 10^{15} \text{ m} \approx 9.5 \times 10^{15} \text{ m} \end{aligned}$$

0 8 . 4

I_A is the intensity of light from Antares at the position of the Earth.

I_S is the intensity of light from the Sun at the position of the Earth.

Calculate $\frac{I_A}{I_S}$

radius of the Earth's orbit around the Sun = 1.5×10^{11} m

[3 marks]

$$I = P / 4\pi r^2 \quad \text{so} \quad I_A/I_S = (P_A/P_S) \times (r_S/r_A)^2$$

$$r_A = 550 \times 9.46 \times 10^{15} = 5.20 \times 10^{18} \text{ m}$$

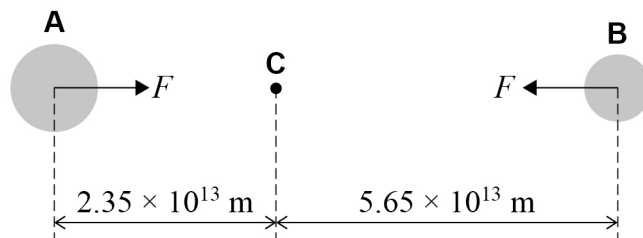
$$I_A/I_S = 7.59 \times 10^4 \times (1.5 \times 10^{11} / 5.20 \times 10^{18})^2$$

$$\frac{I_A}{I_S} = \underline{6.3 \times 10^{-11}}$$



Figure 13 shows a binary system that consists of two stars Antares **A** and Antares **B**. The stars have circular orbits around their common centre of mass **C**. The gravitational forces F between the two stars and their distances from **C** are shown.

Figure 13



mass of **A** = 2.39×10^{31} kg

mass of **B** = 9.95×10^{30} kg

0 8 . 5

Calculate the time taken for Antares **A** to complete one orbit around **C**.

[4 marks]

gravitational force provides the centripetal force on A:

$$GM_A M_B / R^2 = M_A r_A \omega^2$$

$$R = 2.35 \times 10^{13} + 5.65 \times 10^{13} = 8.00 \times 10^{13} \text{ m}, \quad r_A = 2.35 \times 10^{13} \text{ m}$$

$$\omega^2 = GM_B / (R^2 r_A)$$

$$= 6.67 \times 10^{-11} \times 9.95 \times 10^{30} / ((8.00 \times 10^{13})^2 \times 2.35 \times 10^{13})$$

$$\omega^2 = 4.41 \times 10^{-21} \quad \text{so} \quad \omega = 6.64 \times 10^{-11} \text{ rad s}^{-1}$$

$$T = 2\pi / \omega = 2\pi / 6.64 \times 10^{-11}$$

$$\text{time} = \underline{9.5 \times 10^{10}} \text{ s}$$

0 8 . 6

Explain why Antares **A** and Antares **B** must have the same orbital periods around **C**.

[1 mark]

They must always stay on opposite sides of C, on a straight line

through C, otherwise the centre of mass would no longer be on the line

between them.

13

END OF QUESTIONS



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