9 **(a)** State what is meant by the mass defect of a nucleus.

.....

.....

..... [2]

(b) The nuclear fusion reaction for the formation of helium-4 from deuterium is represented by

$$^{2}_{1}\mathrm{H} + {}^{2}_{1}\mathrm{H} \rightarrow {}^{4}_{2}\mathrm{He}.$$

Table 9.1 shows the masses of the nuclides involved in this reaction.

Table 9.1

nuclide	nuclide mass / u
$^{2}_{1}\mathrm{H}$	2.013 553
$^{4}_{2}\mathrm{He}$	4.001 505

Calculate the energy released in the formation of 1.00 mol of helium-4.

energy = ... J [4]

(c) The star Sirius has a radius of 1.19×10^{9} m and loses mass due to nuclear fusion at a rate of $1.09 \times 10^{11}\,\text{kg}\,\text{s}^{-1}$. Assume that the power of the radiation emitted by the star is equal to the power released by this process.

(i) Determine a value for the luminosity of Sirius. Give a unit with your answer.

luminosity = ... unit ..... [2]

(ii) Use your answer in **(c)(i)** to determine the surface temperature of Sirius.

surface temperature = ... K [2]

(d) Explain how cosmologists use standard candles to estimate the distance of a galaxy from the Earth.

.....

.....

.....

.....

..... [3]

[Total: 13]

2 A student investigates the relationship between the luminosity of a star and its mass.

The student obtains data of relative luminosity λ and relative mass μ for six stars, where

$$\lambda = \frac{\text{luminosity of star}}{\text{luminosity of Sun}}$$

and

$$\mu = \frac{\text{mass of star}}{\text{mass of Sun}}.$$

It is suggested that λ and μ are related by the equation

$$\lambda = k\mu^n$$

where k and n are constants.

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

Determine expressions for the gradient and y-intercept.

gradient = ...

y-intercept = ...

[1]

(b) Values of μ and λ are given in Table 2.1.

Table 2.1

μ	λ	lg μ	lg λ
4.6 ± 0.4	500		
5.4 ± 0.4	800		
8.4 ± 0.4	3200		
11 ± 1	7000		
16 ± 1	25 000		
18 ± 1	38 000		

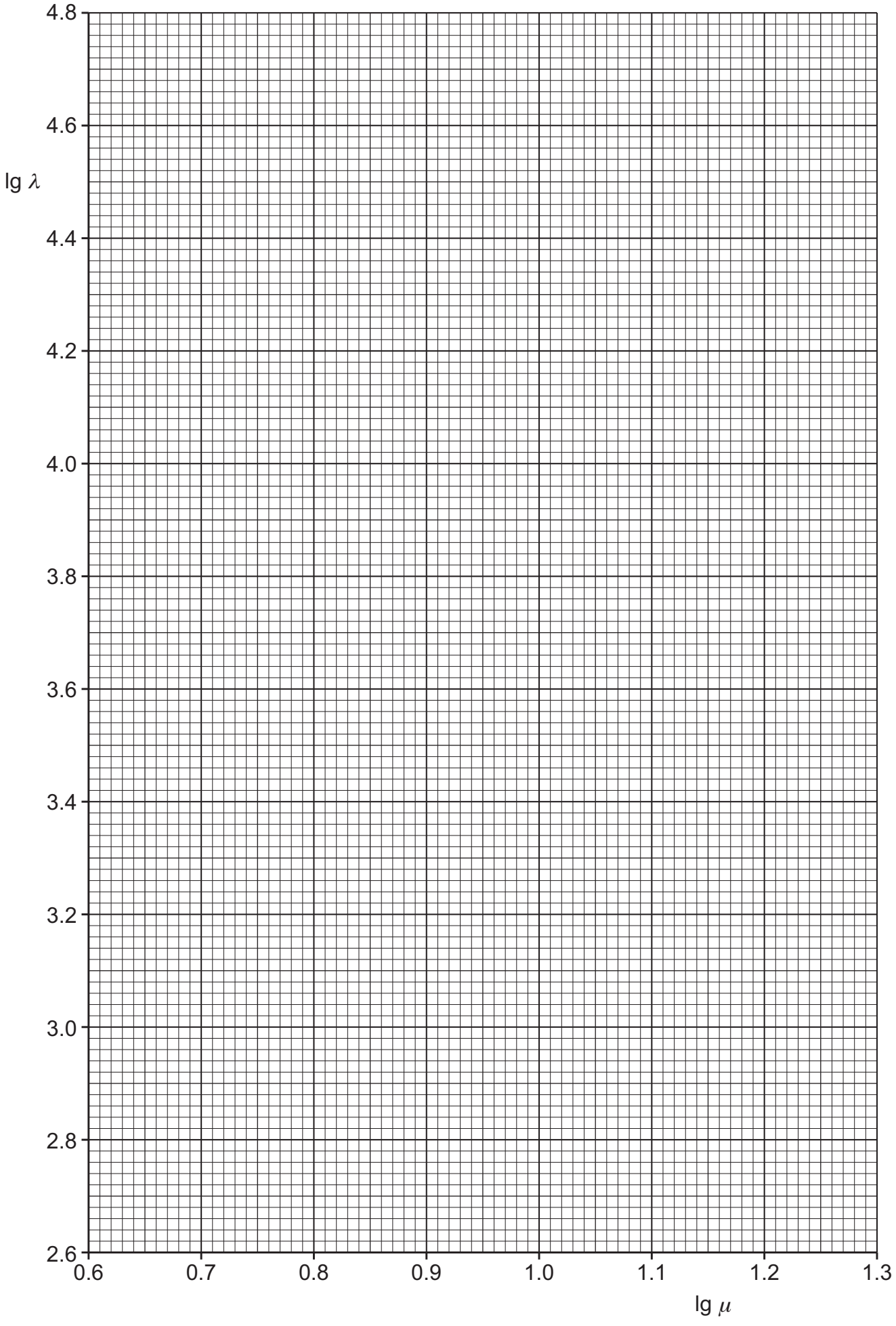
Calculate and record values of lg μ and lg λ in Table 2.1.
Include the absolute uncertainties in lg μ. [2]

(c) **(i)** Plot a graph of lg λ against lg μ.
Include error bars for lg μ. [2]

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

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

gradient = ... [2]


4.8
4.6
lg λ
4.4
4.2
4.0
3.8
3.6
3.4
3.2
3.0
2.8
2.6
0.6
0.7
0.8
0.9
1.0
1.1
1.2
1.3
lg μ

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

y-intercept = ... [2]

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

k = ...

n = ...
[3]

(e) The mass of the Sun is 2.0×10^{30} kg. The star Alpha Centauri B has a value of λ of 0.46.

Determine the mass *M* of Alpha Centauri B.

M = ... kg [1]

[Total: 15]