2 A student investigates light from different galaxies.

Fig. 2.1 shows the lines in the absorption spectrum from a distant galaxy.

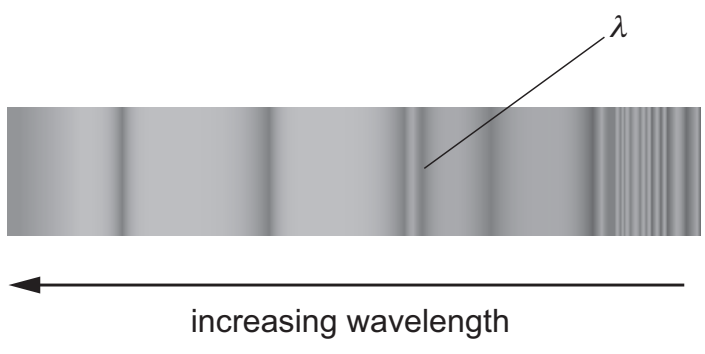


Fig. 2.1

The wavelength of one of the lines in the absorption spectrum is λ. The wavelength of this spectral line in the laboratory is λ_0.

The observations of the same spectral line are repeated for different galaxies.

The student determines the distance d of each galaxy from the Earth.

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

$$\frac{\lambda - \lambda_0}{\lambda_0} = \frac{Hd}{c}$$

where c is the speed of light in free space and H is the Hubble constant.

(a) A graph is plotted of λ on the y-axis against $\frac{d}{c}$ on the x-axis.

Determine expressions for the gradient and y-intercept.

gradient = ...

y-intercept = ...
[1]

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

Table 2.1

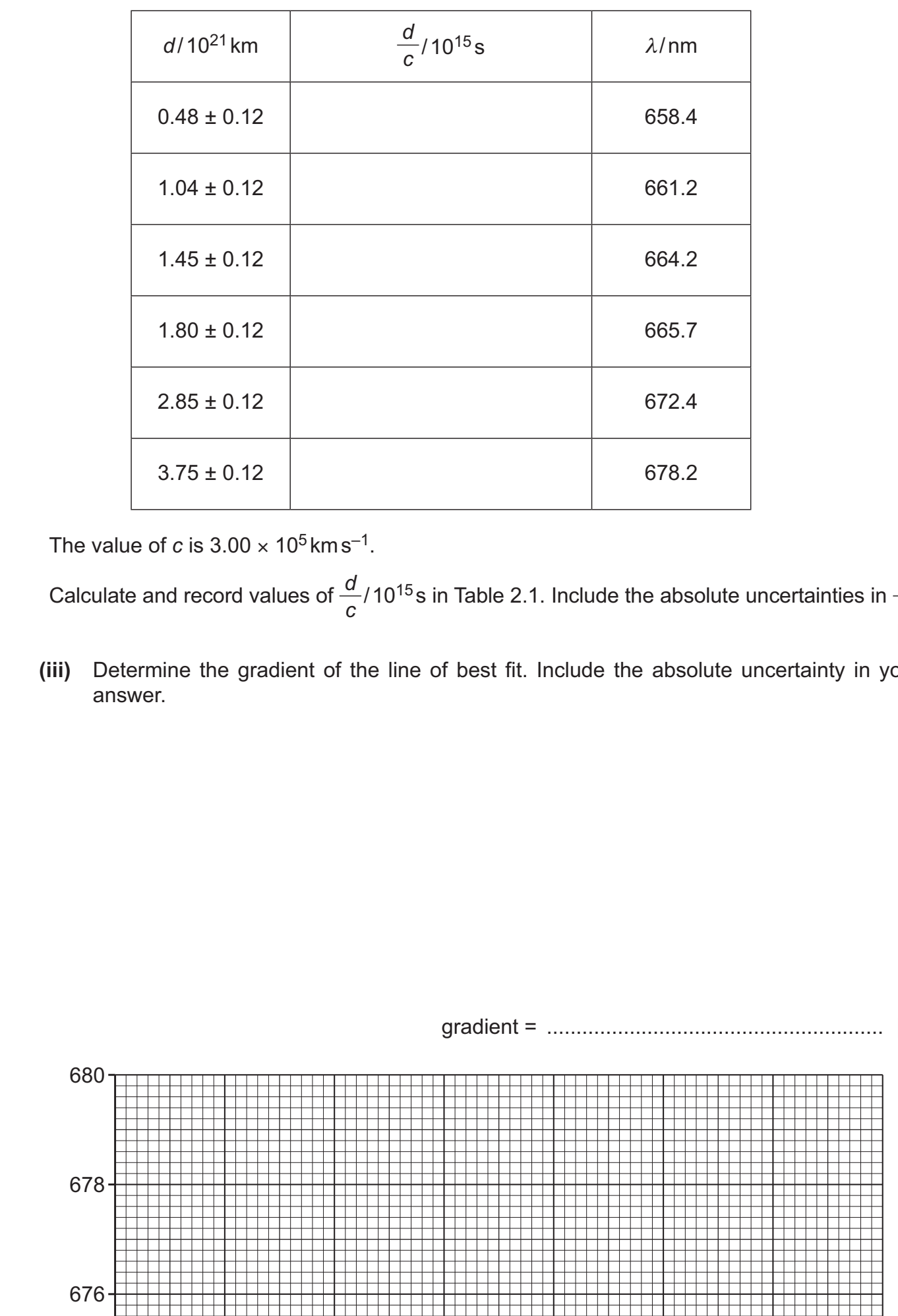
$d/10^{21}$ km	$\frac{d}{c}/10^{15}$ s	λ/nm
0.48 ± 0.12		658.4
1.04 ± 0.12		661.2
1.45 ± 0.12		664.2
1.80 ± 0.12		665.7
2.85 ± 0.12		672.4
3.75 ± 0.12		678.2

The value of c is 3.00×10^5 km s^{-1}.

Calculate and record values of $\frac{d}{c}/10^{15}$ s in Table 2.1. Include the absolute uncertainties in $\frac{d}{c}$.
[2]

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

gradient = ... [2]



(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 λ_0 and H. Include appropriate units.

λ_0 = ...

H = ...
[2]

(e) Hubble's law suggests that the age T of the universe is related to H by

$$T = \frac{1}{H}.$$

Determine a value for T. Include the absolute uncertainty in your answer.

T = ... s [2]

[Total: 15]