3 (a) Figure 2 shows some lines in the absorption spectra from four different galaxies (A, B, C, and D) and from a laboratory source.

All the spectra are aligned and to the same scale.

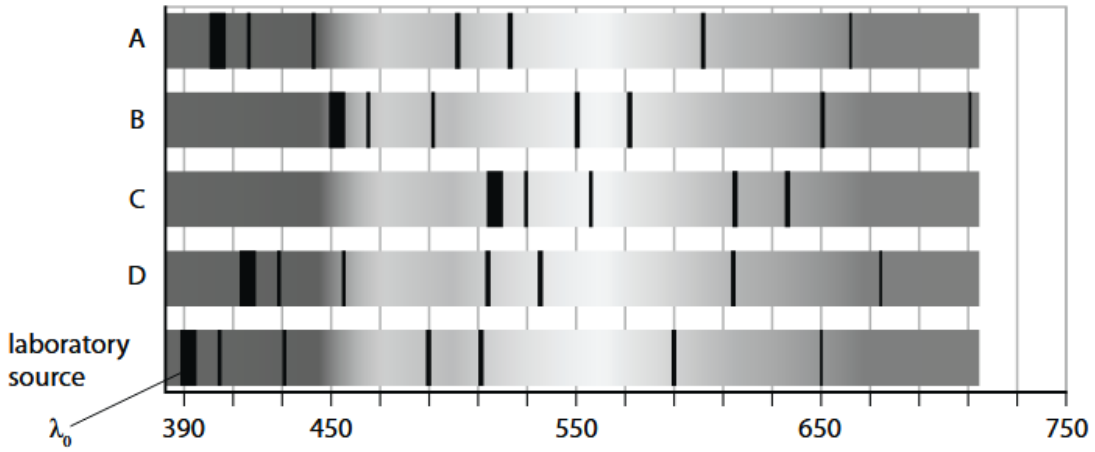

Figure 2

(i) Explain, using Figure 2, which galaxy is furthest away from us.

(3)

.....

.....

.....

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.....

.....

(ii) In Figure 2, the reference wavelength, λ_0, is shown at 390 nm.

Estimate the change in the reference wavelength, $\Delta\lambda$, for the light from galaxy D.

(1)

$\Delta\lambda$ = ... nm

(iii) Calculate the speed, v, of galaxy D.

Use the equation

$$v = c\frac{\Delta\lambda}{\lambda_0}$$

[c = speed of light = 3×10^8 m/s]

(2)

v = ... m/s

(b) Figure 3 shows a photograph of galaxy D.

This photograph was taken by a student at his home.

(Source: Paul Curtis)

Figure 3

State **two** ways that the student can improve the observational techniques so that the quality of the image is improved.

(2)

1 .....

.....

2 .....

.....

(Total for Question 3 = 8 marks)

Question number	Answer	Mark
3(a)(i)	An explanation that combines identification via a judgement (1 mark) to reach a conclusion via justification/reasoning (2 marks): • galaxy C has the greatest red shift (1) • so this galaxy has the greatest speed (1) • since the galaxy with the greatest speed will be furthest away, then galaxy C is at the furthest distance(1)	**(3)**

Question number	Answer	Additional guidance	Mark
3(a)(ii)	20 (nm)	Allow answers in the range 19 to 25	**(1)**

Question number	Answer	Additional guidance	Mark
3(a)(iii)	Substitution (1) $v = \frac{\left(3\times10^{8}\right)\times\left(20\times10^{-9}\right)}{\left(390\times10^{-9}\right)}$ Answer (1) = 15 400 000 (m/s)	allow ecf from (c)(i) power of 10 error = max 1 accept 15 384 615 (m/s) award full marks for correct numerical answer without working	**(2)**

Question number	Answer	Additional guidance	Mark
3(b)	Any **two** from the following improvements: • use wider aperture telescope/camera (1) • better quality objective lens (1) • use longer exposure time while telescope is locked onto star (1) • move telescope to better seeing conditions, e.g. dry desert, higher up a mountain, dark skies (1)	allow improvements from photography, e.g. use longer exposure time use a satellite telescope ignore use pc to adjust the sharpness of the image	**(2)**