M1.(a) Star much brighter than reflected light from planet ✓

Or

Planet very small and distant – subtends very small angle compared to resolution of telescopes

1

(b) Planet and star orbit around common centre of mass that means the star moves towards/away from Earth as planet orbits ✓

1

Causes shift in wavelength of light received from star ✓

1

(c) Light curve showing constant value with dip ✓

1

When planet passes in front of star (as seen from Earth), some of the light from star is absorbed and therefore the amount of light reaching Earth reduced ✓

1

Apparent magnitude is a measure of the amount of light reaching Earth from the star ✓

1

[6]

M2. (a) (use of $m - M = 5 \log(d/10)$ gives)
$3.54 - (-20.62) = 5 \log (d/10)$ **(1)**

$d = 6.7(9) \times 10^{5}$ pc **(1)**

2

(b) use of $\frac{\Delta\lambda}{\lambda} = -\frac{v}{c}$ **(1)**

$$\Delta\lambda = -\frac{0.21121 \times 105 \times 10^3}{3.0 \times 10^8} = -7(.4) \times 10^{-5}$$

$\lambda' = 0.21121 - 7(.4) \times 10^{-5} = 0.21114\,m$ **(1)**

(allow C.E. for incorrect value of Δλ)

2

(c) $t\left(= \frac{d}{v}\right) = \frac{6.79 \times 10^5 \times 3.08 \times 10^{16}}{105 \times 10^3}$ **(1)**

= 2.0×10^{17} s **(1)**

(1.99×10^{17} s)

(allow C.E. for value of d from (a))

2

[6]

M3. (a) (use of $\frac{\Delta\lambda}{\lambda} = -\frac{v}{c}$ gives) $\frac{(660.86 - 656.28)}{656.28} = (-)\frac{v}{3.0 \times 10^8}$ **(1)**

v = (–)2094 km s^{-1} **(1)**

2

(b) graph to show:

correct plotting of points **(1)**

straight line through origin **(1)**

$H = \frac{v}{d}$ = gradient = 70 km s^{-1} Mpc^{-1} **(1)**

(must show evidence of use of graph in calculation)

3

[5]

M4. (a) (i) correct shape of graph (steeper on left of peak) **(1)**

(ii) region to left of peak **(1)**

(iii) ozone **(1)**

(iv) lower temperature, shifts peak (λ_{max}) to longer wavelengths **(1)** $\lambda_{max}T$ = constant **(1)**

max 4

(b) (i) (use of $f = \frac{c}{\lambda}$ gives) $f\left(= \frac{3 \times 10^8}{2.7}\right)$ = 1.1 × 10^8 Hz,

(in range) **(1)**

(ii) (double) Doppler **(1)**

(iii) (reflection off moving object gives double Doppler), frequency shift = 150 Hz

$v = \frac{150 \times 3 \times 10^8}{1.1 \times 10^8}$ **(1)**

(allow C.E. for shift = 300 Hz)

= 4.1 × 10^2 m s^{-1} (towards each other) **(1)**

5

[9]

M5.(a) (i) $\Delta\lambda = \frac{\lambda v}{c}$ **(1)**

(ii) $\Delta\lambda = -\frac{\lambda v}{c}$ **(1)**

(2)

(b) (i) total difference in wavelength = $\frac{2\lambda v}{c}$ **(1)**

$v = \frac{7.8 \times 10^{-12} \times 3.0 \times 10^{8}}{589 \times 10^{-9} \times 2}$ = 1986 [or 2.0×10^{3}] m s^{-1} **(1)**

(ii) $\omega = \frac{v}{r} = \frac{1986}{7.0 \times 10^{8}}$ **(1)**

= 2.8×10^{-6} rad s^{-1} **(1)**

(4)

[6]