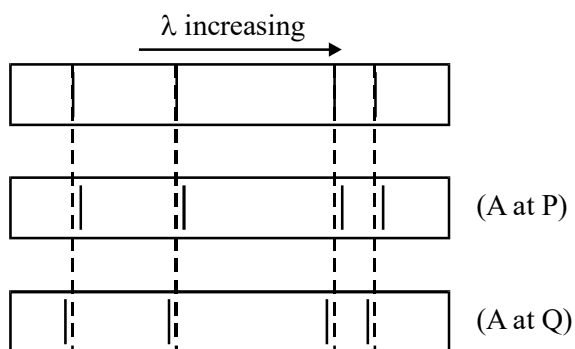


1. (a)



P moving away, Q towards (1)

λ increasing and decreasing respectively (1)

5

(b) (i) $\left(\frac{\Delta\lambda}{\lambda} = \frac{v}{c} \text{ gives}\right) v = \frac{3 \times 10^8 \times 0.8462 \times 10^{-7}}{3.9342 \times 10^{-7}}$ (1)

$= 6.5 \times 10^7 \text{ ms}^{-1}$ (1)

away from Earth (1)

(ii) correct $\lambda = 4.7804 (\times 10^{-7} \text{ m})$ (1)

$v = \frac{3 \times 10^8 \times 0.0132 \times 10^{-7}}{4.7804 \times 10^{-7}}$ (1)

$= 8.30 \times 10^5 \text{ (ms}^{-1}\text{)}$ (1)

period $T = 240$ (day) (1)

$r \left(= \frac{Tv}{2\pi} \right) = \frac{(240 \times 24 \times 60 \times 60) \times (8.3 \times 10^5)}{2\pi}$ (1)

$= 2.73 \times 10^{12} \text{ m}$ (1)

max 7

[12]

2. (a) (i) change in (apparent) frequency [or wavelength] (1)
due to relative motion between source and observer (1)

(ii) from spectrum obtain change in wavelength, $\Delta\lambda$, for a spectral line (1)
using known wavelength measured on Earth (1)

calculate v from $\frac{\Delta\lambda}{\lambda} = (-)\frac{v}{c}$ (1)

(iii) radar or rotation of star (1)
double Doppler effect because body acts as source for return signal (1)
[for rotation, one limb moves towards Earth, one away]

max 6

(b) (i) use of $v = Hd$ (1)

$$v = \frac{5 \times 10^4 \times 4.9 \times 10^7}{3.26 \times 10^6} = 7.5 \times 10^5 \text{ ms}^{-1}$$

$$(ii) \quad \Delta\lambda \left(= \frac{\lambda v}{c} \right) = \frac{7.5 \times 10^5 \times 6.5647 \times 10^{-7}}{3 \times 10^8} = 1.64 \times 10^{-9} \text{ (m) (1)}$$

$$\lambda_{\text{obs}} = (6.5647 + 0.0164) \times 10^{-7} = 6.58 \times 10^{-7} \text{ m (1)}$$

4

[10]

$$3. \quad (a) \quad (i) \quad \Delta\lambda = \frac{\lambda v}{c} \quad \text{(1)}$$

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

2

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

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

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

$$= 2.8 \times 10^{-6} \text{ rad s}^{-1} \quad \text{(1)}$$

4

[6]

4. (a) (quasars are) strong radio sources (1)

1

$$(b) \quad (i) \quad \left(\text{use of } \frac{\Delta\lambda}{\lambda} = (-)\frac{v}{c} \text{ gives} \right) v = (-) \frac{3.00 \times 10^8 \times (382.5 - 279.8)}{279.8} \quad \text{(1)}$$

$$= (-)1.10 \times 10^8 \text{ ms}^{-1} \quad \text{(1)}$$

$$(ii) \quad \left(\text{use of } v = Hd \text{ gives} \right) d = \frac{1.10 \times 10^8}{65 \times 10^3} \quad \text{(1) (= 1700 Mpc)}$$

3

(allow C.E. for value of v from (b)(i))

$$(c) \quad (i) \quad \frac{P_{\text{quasar}}}{(2 \times 10^9)^2} = \frac{P_{\text{sun}}}{(2 \times 10^3)^2} \quad (1)$$

$$\frac{P_{\text{quasar}}}{P_{\text{sun}}} = 10^{12} \quad (1)$$

- (ii) very large power (1)
 large distance away or large redshift (1)
 small size/star like/rapid variation (1)

max 4
 QWC

[8]

5. main features :
 expanding Universe (from single point) (1)
 suggest about 15 billion years ago (1)
 'explosion' - creation of space/matter/time (1)

evidence :

- red shift of distant galaxies (1)
 in keeping with Hubble's law (1)
 Hubble's law can be used to age Universe (1)

max 4
 QWC 2

[4]

6. (a) black hole: large gravitational field or very dense (1)
 escape velocity greater than c (1)
 quasar: large red shift or very far away (1)
 very powerful sources (1)

max 3
 QWC 1

$$(b) \quad R = \frac{2GM}{c^2} = \frac{2 \times 6.67 \times 10^{-11} \times 3 \times 10^9 \times 2 \times 10^{30}}{(3 \times 10^8)^2} \quad (1)$$

$$= 8.9 \times 10^{12} \text{m} \quad (1)$$

2

[5]

7. (a) two stars of different brightness orbit a common axis **(1)**
 most of the time both stars are visible, so brightness is a maximum
 i.e. low value of apparent magnitude **(1)**
 at A, when dimmer star passes in front of brighter star there is an
 increase in apparent magnitude (fall in brightness) **(1)**
 at B, (half a cycle later), the brighter star passes in front of the dimmer,
 brightness falls slightly hence small increase in apparent magnitude **(1)**
 transit time indicate different sizes **(1)**
 width of trough indicates transit times **(1)**

max 4
 QWC 1

- (b) (i) (use of $\Delta\lambda = (-)\lambda \frac{v}{c}$ gives) $\Delta\lambda = 656.28 \times 10^{-9} \frac{400 \times 10^3}{3 \times 10^8}$ **(1)**
 $= 0.88 \times 10^{-9} \text{m}$ **(1)** $(0.875 \times 10^{-9} \text{m})$
 maximum wavelength ($= \lambda + \Delta\lambda$) = $657.16 \times 10^{-9} \text{m}$ and
 minimum wavelength ($= \lambda - \Delta\lambda$) = $655.41 \times 10^{-9} \text{m}$ **(1)**
- (ii) time period = $110 \times 60 = 6600 \text{ s}$ **(1)**
 $2\pi r = vt$ gives $r = \frac{400 \times 10^3 \times 6600}{2\pi}$ **(1)**
 $= 4.2 \times 10^8 \text{m}$ **(1)**
 (allow C.E. for value of t)

6

[10]

8. (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)**
 $v = (-)2094 \text{ km s}^{-1}$ **(1)**

2

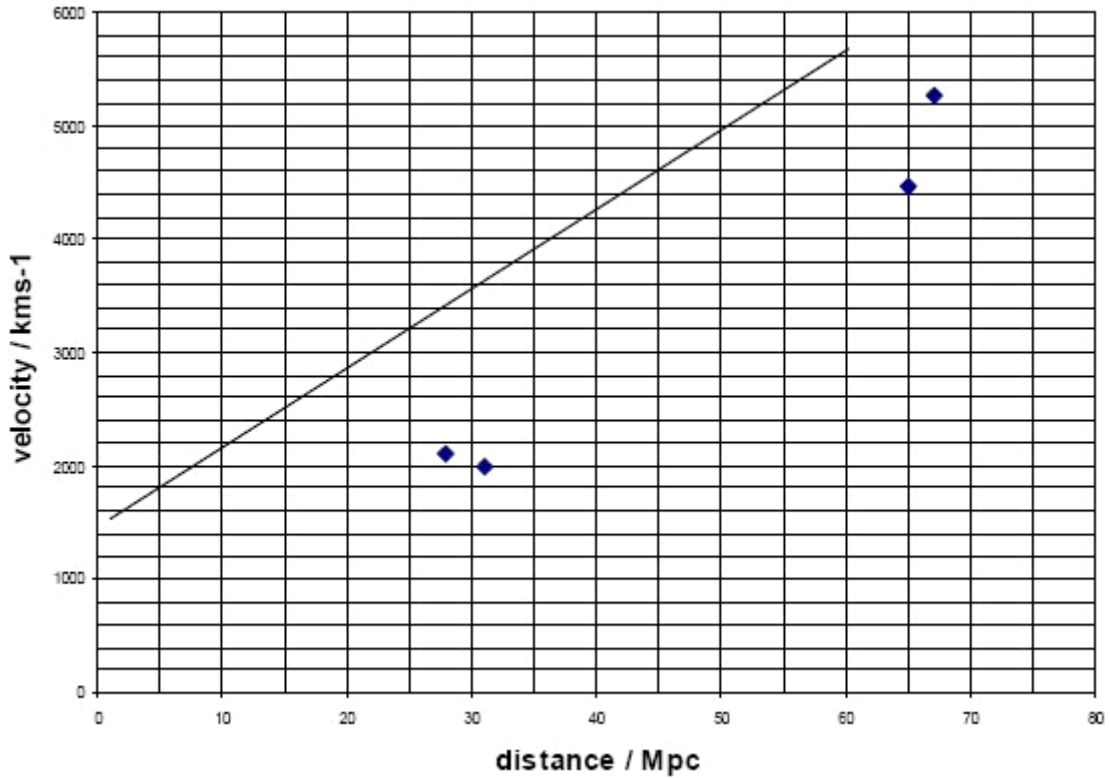
- (b) graph to show:
 correct plotting of points **(1)**
 straight line through origin **(1)**
 $H = \frac{v}{d} = \text{gradient} = 70 \text{ km s}^{-1} \text{ Mpc}^{-1}$ **(1)**

3

(must show evidence of use of graph in calculation)

[5]

9. (a) $\Delta\lambda/\lambda = -v/c$
 $(660.86 - 656.28)/656.28 = (-)v/(3 \times 10^8)$ (1)
 $v = (-) 2094 \text{ km s}^{-1}$ (1)



2

- (b) graph points (1), line through the origin (1)

$H = v/d = \text{slope} = 70 (\pm 4) \text{ km s}^{-1} \text{ Mpc}^{-1}$ (1)

3

- (c) (i) supernovae act as standard candles (1)

known amount of light emitted (absolute magnitude known),
 measured amount detected at Earth (apparent magnitude measured) (1)

inverse square law can be used to determine distance (1)

- (ii) dark energy (1)

max 3

[8]