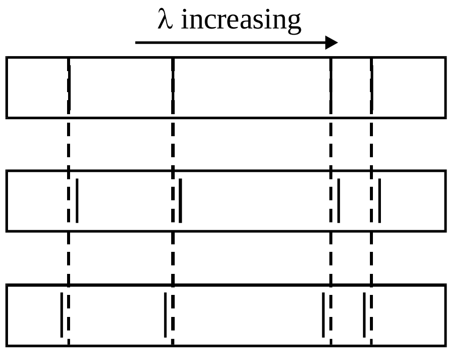
1. (a)



P moving away, Q towards **(1)**

λ increasing and decreasing respectively **(1)** 5

(b) (i) $\left(\frac{\Delta\lambda}{\lambda} = \frac{\upsilon}{c} \text{ gives}\right)$ $\upsilon = \frac{3\times10^{8} \times 0.8462\times10^{-7}}{3.9342\times\times10^{-7}}$ **(1)**

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

away from Earth **(1)**

(ii) correct λ = 4.7804(× 10^{-7} m) **(1)**

$\upsilon = \frac{3\times10^{8} \times 0.0132\times10^{-7}}{4.7804\times10^{-7}}$ **(1)**

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

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

$r\left(= \frac{T\nu}{2\pi}\right) = \frac{(240\times 24\times 60\times 60)\times(8.3\times10^{5})}{2\pi}$ **(1)**

$= 2.73 \times10^{12}$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 υ from $\frac{\Delta\lambda}{\lambda} = (-)\frac{\upsilon}{c}$ **(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 $\upsilon = Hd$ **(1)**

$\upsilon = \frac{5\times10^4 \times 4.9\times10^7}{3.26\times10^6}$ = 7.5 × 10^5 ms^{-1}

(ii) $\Delta\lambda\left(=\frac{\lambda\upsilon}{c}\right) = \frac{7.5\times10^5 \times 6.5647\times10^{-7}}{3\times10^8}$ = 1.64 × 10^{-9} (m) **(1)**

λ_{obs} = (6.5647 + 0.0164) × 10^{-7} = 6.58 × 10^{-7} m **(1)** 4

[10]

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

(ii) $\Delta\lambda = -\frac{\lambda\upsilon}{c}$ **(1)** 2

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

$\upsilon = \frac{7.8\times10^{-12} \times 3.0\times10^8}{589\times10^{-9} \times 2}$ = 1986[or 2.0 × 10^3] m s^{-1} **(1)**

(ii) $\omega = \frac{\upsilon}{r} = \frac{1986}{7.0\times10^8}$ **(1)**

= 2.8 × 10^{-6} rad s^{-1} **(1)** 4

[6]

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

(b) (i) (use of $\frac{\Delta\lambda}{\lambda} = (-)\frac{v}{c}$ *gives*) $v = (-)\frac{3.00\times10^8 \times (382.5 - 279.8)}{279.8}$ **(1)**

= (–)1.10 × 10^8 ms^{-1} **(1)**

(ii) (use of $v = Hd$ gives) $d = \frac{1.10\times10^8}{65\times10^3}$ **(1)** (= 1700 Mpc) 3

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

(c) (i) $\dfrac{P_{\text{quasar}}}{(2\times10^9)^2}=\dfrac{P_{\text{sun}}}{(2\times10^3)^2}$ **(1)**

$\dfrac{P_{\text{quasar}}}{P_{\text{sun}}} = 10^{12}$ **(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) $R=\dfrac{2GM}{c^2}=\dfrac{2\times6.67\times10^{-11}\times3\times10^9\times2\times10^{30}}{(3\times10^8)^2}$ **(1)**

$= 8.9 \times 10^{12}$m **(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 × 10^{-9} $\frac{400\times10^3}{3\times10^8}$ **(1)**
= 0.88 × 10^{-9}(m) **(1)** (0.875 × 10^{-9}(m))
maximum wavelength (= $\lambda + \Delta\lambda$) = 657.16 × 10^{-9} m and
minimum wavelength (= $\lambda - \Delta\lambda$) = 655.41 × 10^{-9}(m) **(1)**

(ii) time period = 110 × 60 =6600 s **(1)**
$2\pi r = vt$ gives $r = \frac{400\times10^3\times6600}{2\pi}$ **(1)**
= 4.2 × 10^8m **(1)**
(allow C.E. for value of *t*) 6

[10]

8. (a) (use of $\frac{\Delta\lambda}{\lambda} = -\frac{v}{c}$ gives) $\frac{(660.86-656.28)}{656.28} = (-)\frac{v}{3.0\times10^8}$ **(1)**
v = (–)2094 km s^{-1} **(1)** 2

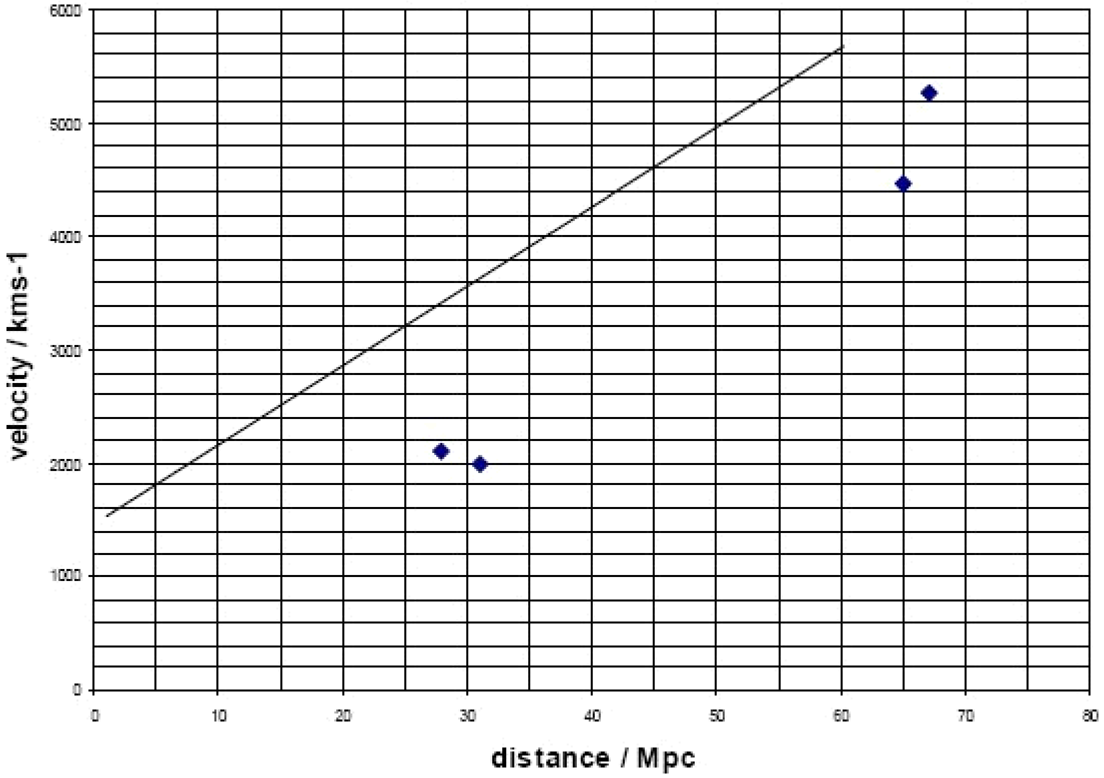
(b) graph to show:
correct plotting of points **(1)**
straight line through origin **(1)**
$H = \frac{v}{d}$ = gradient = 70 km s^{-1} Mpc^{-1} **(1)** 3
(must show evidence of use of graph in calculation)

[5]

9. (a) $\Delta\lambda/\lambda = -v/c$

$(660.86 - 656.28)/656.28 = (-)v/(3 \times 10^8)$ **(1)**

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



2

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

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