13 Our place in the Universe
Answers to practice questions

Question	Answer	Marks
1	D	1
2	Distance = $\frac{1.5\times10^{11}\text{ m}}{\tan\left(2.1\times10^{-4}\right)}$ = 4.1×10^{16} m = 4.3 light-years	1 1 1
3	Speed = 9×10^{6} m s^{-1}	1
4	$\Delta\lambda=\frac{\lambda v}{c}=\frac{v}{f}=\frac{30\times10^{3}\text{ m s}^{-1}}{1\times10^{9}\text{ s}^{-1}}$ = 0.03 mm	1 1
5	$\gamma=\frac{1}{\sqrt{1-0.36}}$ = 1.2	1 1
6 a	km^{-1} × km s^{-1} = s^{-1}	1
6 b	$\frac{1}{\left(\frac{70\text{ s}^{-1}}{3\times10^{19}}\right)}$ = $4.28\ldots\times10^{17}$ s = 1.34×10^{10} years	1 1
7 a	Around 435 nm	1
7 b	$\frac{435-121.6}{121.6}$ = 2.6	1 1
7 c	3.6	1
7 d	Energy of photon received = 4.5×10^{-19} J Energy of emitted photon = 1.6×10^{-18} J	1 1
7 e	Ratio of energies = 3.6 (2 s.f.) Same as the answer to part **d**.	1 1
8 a	For example, for 200 million light-years: expansion speed = 2.1×10^{5} m s^{-1} m.l.y.$^{-1}$ × 200 m.l.y (m.l.y represents 'million light-years') = 4.2×10^{7} m s^{-1} = 0.14 *c*	1 1
8 b	$\gamma=\frac{1}{\sqrt{1-\frac{0.1^{2}}{1}}}$ = 1.005 (This represents less than a 1% difference)	1 1
9 a	$\gamma=\frac{1}{\sqrt{1-\frac{2.7^{2}}{3.0^{2}}}}$ = 2.3	1 1
9 b	$T_{1/2}$ = 2.3 × 18 ns = 41 ns (2 s.f.)	
10 a	$t=\frac{8\times10^{3}\text{ m}}{0.98\times3.0\times10^{8}\text{ m s}^{-1}}$ = 2.72×10^{-5} s	1 1

10 b	$\frac{N}{N_0} = e^{-\frac{0.693 \times 2.72 \times 10^{-5}}{1.5 \times 10^{-6}}}$ $= 3.6 \times 10^{-6}$ = 0.00036%	1 1 1
10 c	Number of half-lives when 8.4% remain = 3.57… Observed half-life = $\frac{2.7 \times 10^{-5}\ \text{s}}{3.57...}$ = 7.6×10^{-6} s $\frac{7.6 \times 10^{-6}\ \text{s}}{1.5 \times 10^{-6}\ \text{s}}$ = 5.1	1 1 1
10 d	$\gamma = \frac{1}{\sqrt{1 - 0.98^2}}$ = 5.02(5) This is (approximately the same factor as in **c**. This agrees with the equation $t = \gamma\tau$	1 1 1 1
11 a	constant speed/velocity/motion (for first five years)	1
11 b i	Light goes 1 light-year in one year (gradient of 1).	1
11 b ii	line starts at t = 1.0 s and goes up and right at 45° to meet spacecraft trace, returning at 45° to reach Earth at 9.0 s.	1 1
11 c i	overall trip time = 8 yr distance = $\frac{8}{2}$ = 4 light-years	1 1
11 c ii	EITHER: pulse delayed by 1 year then takes 4 years to get to spaceship; so event time = 4 + 1 = 5 years OR: Light reaches the spaceship halfway through its trip. Time when it gets there is $\frac{9+1}{2}$ = 5 years	 1 1 1 1
11 c iii	EITHER: $v = \frac{4\ \text{light-years} \times 3 \times 10^8\ \text{m s}^{-1}}{5\ \text{years}}$ = 2.4×10^8 m s^{-1} OR: $v = \frac{4 \times 365 \times 24 \times 3600 \times 3 \times 10^8}{5 \times 365 \times 24 \times 3600}$ = 2.4×10^8 m s^{-1}	 1 1
11 d i	$\frac{1}{\sqrt{1 - \frac{v^2}{c^2}}}$ = 1.67	1
11 d ii	6.0	1