Chapter K

Modelling the Universe

K1 Red Shift and Hubble's Law

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Complete the questions in the table:

	Emitted wavelength /nm	Received wavelength /nm	$\Delta\lambda$ /nm	Red shift as fraction of emitted λ = recession velocity as fraction of c	Recession velocity /m s^{-1}
K1.1	500	550	(a)	(b)	(c)
K1.2	500	(a)	(b)	(c)	3.0×10^6
K1.3	500	480	(a)	(b)	(c)
K1.4	(a)	663	(b)	(c)	-2.1×10^7
K1.5	300	1.1×10^6	(a)	(b)	(c)

K1.6 A specific wavelength called the 'calcium K-line' is measured on Earth in laboratories (using a stationary calcium plasma) as 393.4 nm. A galaxy is moving away from our own at a speed of 100 km s^{-1}. It is observed using telescopes on Earth, and the apparent wavelength of the calcium K-line is measured. What is the value of the wavelength as measured through the telescope?

a) What is the value of the wavelength as measured through the telescope?

b) Assuming a value of the Hubble constant of 70 km s^{-1} Mpc^{-1}, calculate the distance of the galaxy from the Earth.

K1.7 The Ursa Major cluster of galaxies is about 200 Mpc from Earth.

a) How far away is this in metres?
b) Convert the value for the Hubble constant in question K1.6(b) into S.I. units (s^{-1}).
c) Estimate the recession velocity of the Ursa Major cluster in m s^{-1}.

NB - Question K1.5(c) is a wavelength within the cosmic microwave background radiation. You don't need a superlumic speed of recession for a very large red-shift – you just need the Universe to have got nearly 4000 times bigger, stretching the wavelength of light within it…

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K2 Exponential Extrapolation

It is advisable to have completed section J3 before beginning this one.

K2.1 If 45% of the unstable nuclei in a sample take 50 s to decay, calculate the decay constant in s^{-1}.

K2.2 If 70% of the light falling on a 5.0 mm thick block of coloured material emerges from the other side, calculate the attenuation coefficient of the material in mm^{-1}.

K2.3 After a period of 3.0 minutes, only 20% of the original charge remains on a capacitor. Calculate the time constant RC of the circuit.

K2.4 In a stage light, 8.0 W of light pass into a 0.70 mm thick filter, of which 6.5 W is absorbed. Calculate the attenuation coefficient of the material.

K2.5 A sample has an initial activity of 3300 Bq. After 15 minutes, the activity is 1230 Bq. What will the activity be after a further 15 minutes?

K2.6 The voltage across a capacitor is 11.5 V. One hour later, it is 7.2 V. What will the voltage be 3.0 hours after the original measurement?

K2.7 It is said to be safe to view the Sun through a filter if it only lets 10^{-5} of the light through. Suppose you have some material which lets 2.0% of the light through. How many sheets do you need to put together back-to-back before you can safely look through it at the Sun? NB - Never make your own filter for viewing the Sun in this way! Most filters bleach at very high intensities and aren't designed for eye protection, so the quality is not good enough for a device to prevent blindness.

K2.8 The attenuation coefficient for a particular beta decay is 2.4 mm^{-1} through aluminium. What thickness of aluminium is needed to reduce an initial count rate of 5.0×10^5 s^{-1} to background levels of 5.0 Bq?