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…

$^7/_9$

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?

K2.9 The thickness of lead needed to stop half of the neutrinos in a beam is about 3000 light years (which you may take as 3.0×10^{19} m). Calculate the fraction of neutrinos which would be stopped by 100 m of water assuming that the attenuation co-efficients for water and lead are about the same (which they're not).

Optional, but related, and useful:

K2.10 You start with a credit card debt of £150. For each month in which you don't pay it off, the debt increases by 3.0%. Assuming you pay nothing for 3.0 years, and then want to settle the debt in one go, how much would you have to pay?

K3 Black Body Radiation and Wien's Displacement Law

$^7/_9$

K3.1
a) What intensity of radiation is emitted by a black body at 305 K?
b) What thermal radiation power is emitted by a human, modelled as a black body of temperature 305 K and surface area 1.8 m^2?

K3.2 The temperature of a black body increases from 300 K to 800 K. By what factor does its thermal radiation power increase?

K3.3 An incandescent light bulb filament operates at a temperature of 3200 K. The total power of black-body radiation emitted from the filament is 5.0 W. What is the effective surface area of the filament?

K3.4 The Sun emits black-body radiation at its surface temperature of 5770 K. At what wavelength is the peak in the emission spectrum?

K3.5 A red dwarf star emits radiation in a black-body spectrum whose intensity peaks at 950 nm. What is the surface temperature of the star?

K3.6 Towards the end of its life, a main sequence star becomes a red giant. During this transition, its surface temperature changes from 5000 K to 3500 K and its radius increases from $650\,000$ km to 200 million km. By what factor does its power increase?

K3.7 Modern infrared temperature sensors must be able to identify whether a person has a fever. One way to do this might be to track changes in the wavelength λ_{max} at which their thermal radiation has a peak in intensity.
a) What is the value of λ_{max} for a person without fever, whose forehead temperature is 35 °C?
b) By how much does λ_{max} change when a person develops a mild fever, and their forehead temperature rises to 37 °C?