Chapter 1

(1) page 20, question 2

$$3 \times 10^5 \text{ km/s} \times \left( \frac{10^3 \text{ m}}{1 \text{ km}} \right) = 3 \times 10^8 \text{ m/s}$$

$$3 \times 10^5 \text{ km/s} \times \left( \frac{10^5 \text{ cm}}{1 \text{ km}} \right) = 3 \times 10^{10} \text{ cm/s}$$

(2) page 20, question 8, you will need to use the tables on page A-1

(a)

$$4.2 \text{ AU} \times \left( \frac{1.5 \times 10^8 \text{ km}}{1 \text{ AU}} \right) = 6.3 \times 10^8 \text{ km}$$

$$6.3 \times 10^8 \text{ km}/(20 \text{ km/s}) = 3.15 \times 10^7 \text{ s} \approx 1 \text{ year}$$

(b) Yes! The Earth will be at approximately the same location because this is one year (one orbit around the Sun) later.

(3) Time to practice scientific notation

(a) Write 252042.12 in scientific notation.

$$2.5204212 \times 10^5$$

(b) Write 0.0006849 in scientific notation.

$$6.849 \times 10^{-4}$$

(c) Write $8.19 \times 10^{-6}$ as an ordinary string of digits.

$$0.00000819$$

(d) Write $7.83 \times 10^7$ as an ordinary string of digits.

$$78300000$$

(4) page 20, question 19

Remember that 2 minutes is equal to 120 seconds.

$$4 \times 10^3 \text{ m/s} \times 120 \text{ s} = 4.8 \times 10^5 \text{ m}$$

The answer is $e$. 

1
Gamma rays have a shorter wavelength and a higher frequency than radio waves. Also, individual gamma ray photons have a higher energy than radio wave photons.

We know the composition of star by their absorption lines. The continuum (blackbody) radiation from below transmits through the cooler atmosphere where absorption by atoms imprint their characteristic fingerprints on the spectrum.

The spectral line from the left is shorter, thus it is blueshifted and corresponds to material coming toward us. Conversely, on the right the emission is redshifted and must be moving away from us. The rotation must then be from left to right, or if you were looking from above, counterclockwise.

The Earth’s average temperature is 80.6 °F. What is it’s average temperature in °C? What about in Kelvin?

\[
\frac{5}{9} \times (80.6 \degree F - 32) = 27 \degree C
\]

\[27 \degree C + 273 = 300 \text{ K}\]

As the iron rod heats, its corresponding black body temperature increases. This causes it to emit at smaller and smaller wavelengths, as prescribed by Wien’s law. The sequence from red to orange to white light (what we see when a blackbody is centered near the yellow or green) is exactly this ordering from long to shorter wavelength light.

\[
4861 \text{ Å} \times \left(\frac{1 \times 10^{-10} \text{ m}}{1 \text{ Å}}\right) = 4.861 \times 10^{-7} \text{ m}
\]

Using \(\lambda \nu = c\),

\[
\frac{3 \times 10^8 \text{ m/s}}{4.861 \times 10^{-7} \text{ m}} \approx 6.2 \times 10^{14} \text{ Hz}
\]

(b) Since \(\nu \propto \frac{1}{\lambda}\), if the wavelength is doubled, then the frequency is cut in half. The wavelength of the H\(\alpha\) line is 6563 Å. Converting to meters

\[
6563 \text{ Å} \times \left(\frac{1 \times 10^{-10} \text{ m}}{1 \text{ Å}}\right) = 6.563 \times 10^{-7} \text{ m}
\]

Doubling this wavelength, we find

\[
\frac{3 \times 10^8 \text{ m/s}}{1.3 \times 10^{-6} \text{ m}} \approx 2.3 \times 10^{14} \text{ Hz}
\]

95 MHz corresponds to a frequency of \(9.5 \times 10^7\) Hz. The wavelength is then given by \(\lambda \nu = c\), so

\[
\frac{3 \times 10^8 \text{ m/s}}{9.5 \times 10^7 \text{ Hz}} = 3.2 \text{ m}
\]
Note that the units work out perfectly fine because Hz = 1/s = s\(^{-1}\).

(12) page 36, question 26
(a) Since \( E \propto \nu \), if a photon is has 10 times the frequency, then it also has \boxed{10 times} the energy.
(b) Since \( \nu \propto 1/\lambda \), if a photon has twice the wavelength, then energy is a \boxed{factor of 2 less}

(13) page 36, question 30
For a spherical black body, the luminosity (the energy emitted per second) is given by \( L \propto R^2T^4 \). Since we are comparing two black bodies of the same size, we can ignore the \( R \) dependence, which gives \( L \propto T^4 \) or \( T \propto L^{1/4} \). Since the star is 2 times as luminous, the temperature must be \boxed{2^{1/4} \approx 1.2} times hotter.

(14) You obtain a spectrum from a star. Suppose the H\( \alpha \) line (the first hydrogen Balmer line), which is at \( \lambda_0 = 6562.8 \text{ Å} \) in laboratory measurements, is observed to be at a wavelength of \( \lambda = 6556.7 \text{ Å} \).
(a) Is this star approaching or receding from you? What effect are you basing your conclusion on?
Since the observed wavelength is shorter than the rest frame wavelength, the star must be \boxed{approaching you} (it’s blueshifted). This is based on the \underline{Doppler effect}
(b) How fast is the star traveling?
The Doppler effect equation is \( \Delta \lambda/\lambda = v/c \). Solving for the velocity
\[ v = \frac{\lambda - \lambda_0}{\lambda_0} c = \frac{-6.1 \text{ Å}}{6562.8 \text{ Å}} c = -9.3 \times 10^{-4} c \approx -278 \text{ km/s} \]
The negative velocity confirms that the source is moving toward you.

Chapter 3

(15) page 59, question 3
Large ground-based telescopes are large enough that the defraction limit is not a problem. The limiting factor is instead turbulence in the Earth’s atmosphere. This limits the resolution to be larger than approximately 1”.

(16) page 59, question 13
The collecting power goes like the area, so that it is proportional to the diameter squared. A 3 meter telescope can gather \boxed{3^2 = 9} times as much light as a 1 meter telescope.
Similarly, in comparison to a 6 mm = 6 \times 10^{-3} \text{ m} diameter human eye (the pupil), the 3 meter telescope can gather \boxed{(3/6 \times 10^{-3})^2 = (500)^2 = 2.5 \times 10^5} times as much light.

(17) page 59, question 14
Taking the ratio of the diameters squared \boxed{(10/5)^2 = 2^2 = 4} times as much light.

(18) page 59, question 16
The resolution is \textit{proportional} to the wavelength of the light being observed and \textit{inversely proportional} to the diameter of the telescope. Since red light has a longer wavelength, its resolution is poorer than for blue light. If a pair of stars are sufficiently close, then the poorer resolution of the red light could make it difficult to distinguish that there are actually two stars, while for blue light the two stars can be perfectly resolved.