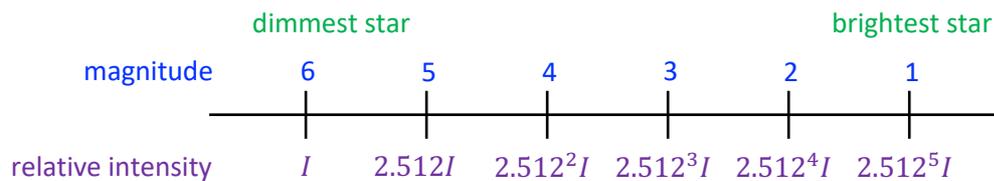## 9.2.1 Apparent magnitude

Apparent magnitude (m) is a measure of the brightness of a star as seen by an observer on Earth. It is a logarithmic scale, because this is how the eye responds to the intensity of light. The magnitude scale is based on the practice in Hellenistic times of assigning 6 levels of brightness to stars in the night sky. The very brightest stars were given a magnitude of *1* and the faintest stars were given a magnitude of *6*. As the scale is logarithmic, progressing from one magnitude to the next involves an increase in light intensity of 2.512 times.
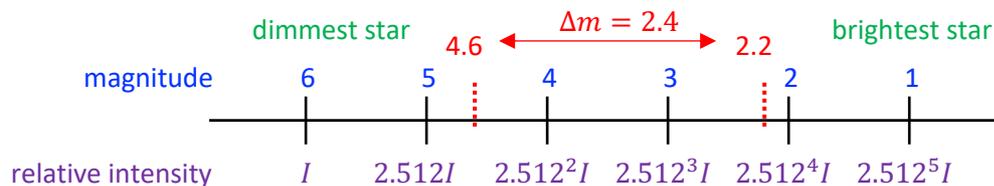
	dimmest star					brightest star
magnitude	6	5	4	3	2	1
relative intensity	I	$2.512I$	2.512^2I	2.512^3I	2.512^4I	2.512^5I

This means that a magnitude *5* star has 2.512 times the intensity of a magnitude *6* star. A magnitude *4* star has 2.512^2=6.3 times the intensity of a magnitude *6* star.

(1)✎ How much more intense will a magnitude 2 star be than a magnitude 5 star?

In fact, there are 5 steps between a magnitude *6* (dimmest) and a magnitude *1* star. So, a magnitude *1* star has $2.512^5 = 100$ times greater intensity than a magnitude *6* star. You can see that the value 2.512 (known as Pogson's Ratio), is just $\sqrt[5]{100}$.

In problems involving magnitude you will often be asked to compare the 'brightness' of two stars, given their apparent magnitudes.

Consider the following:

	dimmest star		4.6	$\Delta m = 2.4$	2.2		brightest star
magnitude	6	5		4	3		2	1
relative intensity	I	$2.512I$		2.512^2I	2.512^3I		2.512^4I	2.512^5I

Let us compare the brightness of two stars with apparent magnitudes of *4.6* and *2.2*. First of all, you need to recognise that the smaller magnitude is brighter than the larger magnitude star. The brighter star has $2.512^{(4.6-2.2)} = 2.512^{2.4} = 9.1$ times the intensity of the dimmer star.

(2)✎ Find the ratio of the intensities of the light that reaches the Earth from two stars whose apparent magnitudes are 1.4 and 3.9

With the development of telescopes, it is now possible to view stars which we couldn't with the naked eye. Additionally, there are objects in the sky that are brighter than magnitude 1 (e.g. some planets, the Moon, some very bright stars). This means that the magnitude scale needs to be extended in both directions:
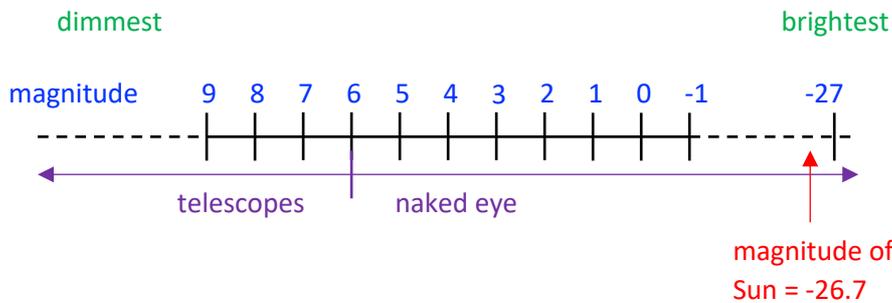
Again, if you are asked to compare the brightness of two stars with apparent magnitudes m_1 and m_1, the ratio of their intensities is given by:

$$\frac{I_1}{I_2} = 2.512^{(m_2 - m_1)}$$

where star 1 is brighter than star 2.

Be particularly careful with negative magnitudes!

Consider the following worked example:

Sirius has an apparent magnitude of 1.47. How much brighter is the Sun ($m_s = -26.7$) than Sirius?

$$\frac{I_{Sun}}{I_{Sirius}} = 2.512^{(1.47 - (-26.7))} = 2.512^{28.2} = 1.91 \times 10^{11}$$

The Sun is 1.91×10^{11} times brighter than Sirius!

(3) ✐ Compare the brightness (intensities) of the new Moon ($m_M = -2.5$) with the Sun.

Another problem you may encounter is working out the magnitude of one of two stars, given the ratio of their intensities and the magnitude of one of the stars.

$$\frac{I_1}{I_2} = 2.512^{(m_2 - m_1)}$$

given → $\frac{I_1}{I_2}$

given ↗ m_1

unknown ↘ m_2

where star 1 has a greater intensity

You then need to do a bit of rearranging

(4)✎ Show that: $\quad m_1 = m_2 - \dfrac{\ln\left(\frac{I_1}{I_2}\right)}{\ln(2.512)}$

(5)✎ The intensity of the light that reaches the Earth from a particular star is seven times greater than that from a star whose apparent magnitude is 3.6. What is the apparent magnitude of the brighter star?