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Unthinkably small, unimaginably large

Specification references:

- P6.1.2 4 Properties of waves
- WS3.3, WS4.4

Aims

You will be learning how to use standard notation numbers to represent large and small numbers, as well as solving calculations with them.

Learning outcomes

After completing this worksheet, you should be able to:

- use standard notation when dealing with large and small numbers
- explain how electromagnetic radiation spans across a very wide range of wavelengths and frequencies.

Setting the scene

Electromagnetic radiation is all around us all the time. There are many sources of electromagnetic waves, such as the Sun, radio transmitters, mobile phones, distant stars, and artificial satellites.

Harnessing the ability of electromagnetic radiation to transfer energy and information has brought technological advances that were literally unimaginable nearly 150 years ago, before James Clerk Maxwell published his theory of electromagnetic fields in 1865. Thanks to electromagnetic waves we can develop wireless devices, communicate across different continents almost instantaneously and remotely control spacecraft and rovers sent to distant locations in space, like the Curiosity rover that landed on Mars on the 6th August 2012.

The electromagnetic spectrum spans across a very large range of wavelengths and each frequency of electromagnetic radiation has different properties that can be used in specific applications, for example wavelengths between 400 and 780 nm can be detected by the human eye and allow us to see the world around us.

Worked example

You will need to use the following calculations in the questions below:

Standard form numbers are useful when dealing with very small, or very large numbers. For example, $3.2 \times 10^{7} = 32\,000\,000$ (i.e., 32 million) and $3.2 \times 10^{-7} = 0.000\,000\,32$.

When working with S.I. units we use the prefixes in the table below to abbreviate the numbers we need to write for such small and large quantities.

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Metric prefixes in everyday use			
Text	**Symbol**	**Factor**	**Power**
exa	E	1 000 000 000 000 000 000	10^{18}
peta	P	1 000 000 000 000 000	10^{15}
tera	T	1 000 000 000 000	10^{12}
giga	G	1 000 000 000	10^{9}
mega	M	1 000 000	10^{6}
kilo	k	1 000	10^{3}
hecto	h	100	10^{2}
deca	da	10	10^{1}
(none)	(none)	1	10^{0}
deci	d	0.1	10^{-1}
centi	c	0.01	10^{-2}
milli	m	0.001	10^{-3}
micro	μ	0.000 001	10^{-6}
nano	n	0.000 000 001	10^{-9}
pico	p	0.000 000 000 001	10^{-12}
femto	f	0.000 000 000 000 001	10^{-15}
atto	a	0.000 000 000 000 000 001	10^{-18}

In the questions below you will also need to apply the wave speed equation $v = f \times \lambda$ and remember that the speed of electromagnetic waves in space and air is $c = 3 \times 10^8$ m/s.

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Questions

1 These questions are about very distant objects and the speed of light.

a Proxima Centauri is the closest star to the Earth after the Sun. The distance between the Earth and Proxima Centauri is about 40 Pm (petametres), so how long will it take a beam of light to travel from Proxima Centauri to a telescope on Earth? Give your answer in seconds, in days, and in years.

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b Sirius is the brightest star visible in the night sky and its distance from the Earth is 8.611 light years. That means that it takes 8.611 years for light to travel from Sirius to the Earth through space. What is this distance in meters?

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..... (*4 marks*)

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c An ultraviolet telescope is measuring radiation coming from the Sun of wavelength 150 nm. Calculate the frequency of this ultraviolet light emitted by the Sun.

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(*4 marks*)

2 These questions are about very small objects and electromagnetic waves.

a Diffraction of green laser light can be used to investigate structures of similar sizes to the wavelengths of green light, for example 520 nm. What is the frequency of this light?

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(*3 marks*)

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b X-ray radiation of frequency 3.3×10^{18} Hz is used to investigate a very small structure. What is the size of this structure?

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..... (*4 marks*)

c A set of Bluetooth headphones connects to a smartphone with a radio signal of frequency 2.4 GHz. Calculate the wavelength of this signal in cm.

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