Magna Academy Y12 Physics Summer Preparation Task 2023

Contents

Total time taken 10 hours

Maths Skills

Mathematics is the language of physics. Just like every language, it has its own rules and conventions. Unlike other languages, it is used to talk about the fundamental nature of the Universe! We need to learn these rules to study physics.

1. Rearranging Equations

Re-arrange the equations in the table for the quantity in the second column. Use your previous physics knowledge and research skills to find the name of the equation or what it is used for.

Equation	Rearrange for…	Answer	What is this equation?
$c = f\lambda$	f	$f = \frac{c}{\lambda}$	The Wave Equation
$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2}$	R_T	$R_T = \frac{R_1 \cdot R_2}{R_1 + R_2}$	Total Parallel Resistance
$F = \frac{Gm_1m_2}{r^2}$	m_1	$m_1 = \frac{F \cdot r^2}{G \cdot m_2}$	Newton's Law of Gravitation
$hf = \phi + E_{k(max)}$	ϕ	$\phi = hf - E_{k(max)}$	Einstein's Photoelectric Equation

$T = 2\pi\sqrt{\frac{l}{g}}$	g	$g = \frac{4l\pi^2}{T^2}$	Pendulum Simple Harmonic Motion

2. Using Standard Form

In physics we work with numbers that are very large, for example, the radius of the Solar System is:

$$4545000000000 \text{ metres}$$

And numbers that are very small, for example, the mass of a proton:

$$0.00000000000000000000000000167 \text{ kilograms}$$

For these, we can write the number in **standard form:**

$$\boldsymbol{n \times 10^{a}}$$

where *n* is a decimal number between 1 and 10, and *a* is an integer. *a* can be positive (for large numbers) or negative (for small numbers).

To convert a large number into standard form, you can move the decimal point *a* places to the left, until the number is now between 1 and 10, then multiply it by 10^{a}. Similarly, to convert a small number into standard form, move the decimal point *a* places to the right and multiply by 10^{-a}. This makes the radius of the Solar System and the mass of a proton, respectively:

$$4.545 \times 10^{12} \text{ metres}$$

$$1.67 \times 10^{-27} \text{ kilograms}$$

Fill out the table below to practice.

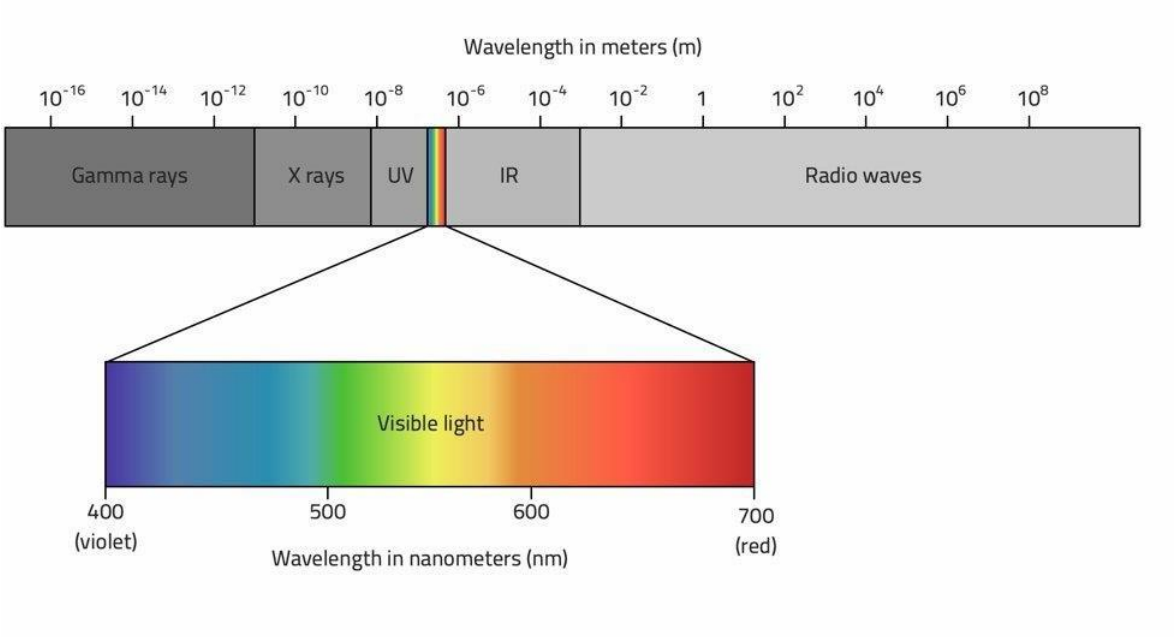
Convert into standard form		Convert from standard form to full number	
65345	6.5345×10^{4}	8.34×10^{-3}	0.00834
0.0053	5.3×10^{-3}	5×10^{4}	50000
0.987	9.87×10^{-1}	9.1×10^{-1}	0.91

3. Using Prefixes

Prefixes are another way to write very large or very small quantities. They're especially useful when trying to convey information *verbally* – it takes less time to say "3 milliseconds" than "3 times 10 to the power of negative 3 seconds". When using prefixes, the number in front of the prefix does not need to be between 1 and 10.

Prefix	Symbol	Power of 10	Multiplication factor
Tera	T	10^{12}	1 000 000 000 000
Giga	G	10^{9}	1 000 000 000
Mega	M	10^{6}	1 000 000
kilo	k	10^{3}	1000

deci	d	10^{-1}	0.1	1/10
centi	c	10^{-2}	0.01	1/100
milli	m	10^{-3}	0.001	1/1000
micro	μ	10^{-6}	0.000 001	1/1 000 000
nano	n	10^{-9}	0.000 000 001	1/1 000 000 000
pico	p	10^{-12}	0.000 000 000 001	1/1 000 000 000 000
femto	f	10^{-15}	0.000 000 000 000 001	1/1 000 000 000 000 000

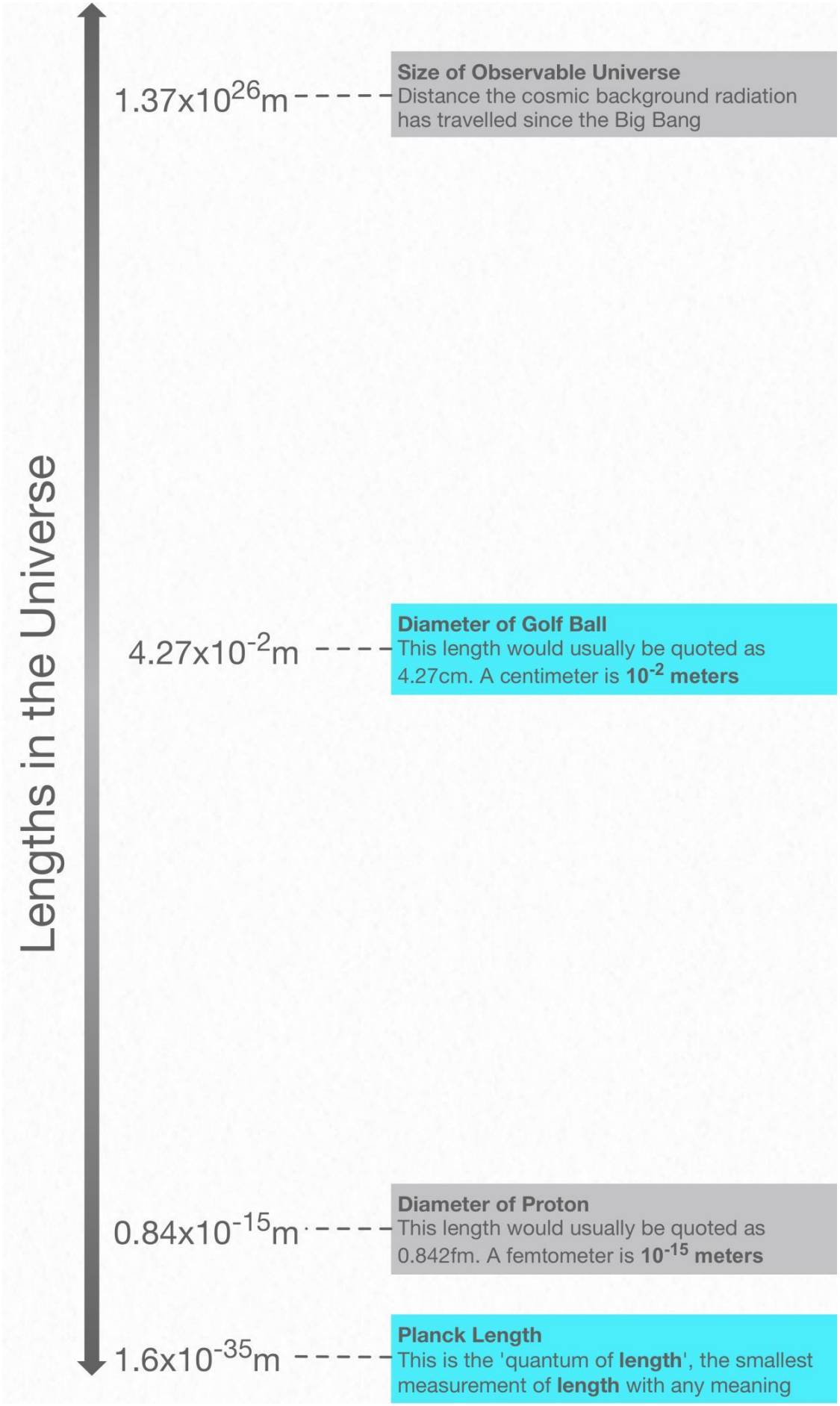


The wavelength of visible orange light can either be written 0.00000000006 metres (full number) or 6×10^{-11} metres (standard form) or 600 nanometres (using a prefix). Fill out the table below to practice.

Number	Standard form?	Using a suitable prefix?
0.000008 metres	8×10^{-6} m	8 μm
1978 grams	1.978×10^{3} g	1.978 kg
0.02 Amps	2×10^{-2} A	2 cA (No prefix preferred)
560000 degrees Kelvin	5.6×10^{5} K	0.56 MK
0.009 seconds	9×10^{-3} s	9 ms

4.1 Research Activity:

Use https://quantumtocosmos.ca/ and/or your own resources to find the lengths of some objects in the universe. Add them to the scale below. Write the number in standard form OR use a prefix when appropriate (or both!)


Lengths in the Universe
1.37x10^26m
Size of Observable Universe
Distance the cosmic background radiation has travelled since the Big Bang
4.27x10^-2m
Diameter of Golf Ball
This length would usually be quoted as 4.27cm. A centimeter is 10^-2 meters
0.84x10^-15m
Diameter of Proton
This length would usually be quoted as 0.842fm. A femtometer is 10^-15 meters
1.6x10^-35m
Planck Length
This is the 'quantum of length', the smallest measurement of length with any meaning

4. SI and Non-SI Units

All sciences use the SI (*Système International*) units. This system is made of 3 parts, (1) the base units (2) the prefixes (see above) and (3) derived units.

4.1 Research Activity:

What are the seven base units of the modern SI? What quantities do they measure? What symbol is used for them? Fill out the table below.

Unit	Quantity	Symbol
Second	Time	s
Metre	Length	m
Kilogram	Mass	kg
Ampere	Electric Current	A
Kelvin	Thermodynamic Temperature	K
Mole	Amount of Substance	mol
Candela	Luminous Efficacy	cd

You need to know how to convert into SI units from common non-SI units:

Quantity	Alternative unit	Value in SI units
Energy	Electronvolt, eV	$1.6 \times 10^{-19}\ \mathrm{J}$
Charge	Elementary charge unit, e	$1.6 \times 10^{-19}\ \mathrm{C}$
Mass	Atomic mass unit, u	$1.67 \times 10^{-27}\ \mathrm{kg}$
Length	Astronomical unit, AU	$3.09 \times 10^{11}\ \mathrm{m}$
Length	Light-year, ly	$9.46 \times 10^{15}\ \mathrm{m}$

(a) The nearest star, other than our Sun, to Earth is Proxima Centauri, which is 4.24 light years away. How far is this in metres? Give your answer in standard form.

$4.01104 \times 10^{16}\ \mathrm{m}$

(b) An atom of lead-207 has a mass of 207.9766521 u. Convert this to kg. Give your answer in standard form.

$3.47321009 \times 10^{-25}\ \mathrm{kg}$

(c) It has been 57 years (365.25 days) since England won the World Cup. How long is this in seconds? Use a suitable prefix for your answer.

$1.798783200\ \mathrm{ns}$

(d) The semi-major axis of Pluto's orbit around the Sun in 5.91×10^{12} metres. What is this distance in AU?

$19.1262136\ \mathrm{AU}$

5. Areas and Volumes

Convert the following areas and volumes in to m^2 and m^3 respectively:

$25\ \mathrm{mm}^2$	2.5×10^{-5}	m^2
$654\ \mathrm{mm}^3$	6.54×10^{-7}	m^3
$0.092\ \mathrm{km}^2$	9.2×10^{4}	m^2
$15\ \mathrm{cm}^3$	1.5×10^{-5}	m^3
$54\ \mathrm{cm}^2$	5.4×10^{-3}	m^2
$0.32\ \mathrm{km}^3$	3.2×10^{8}	m^3

Compute the following areas and volumes. Give your answer in m^2 and m^3. Give your answer in standard form if appropriate.

(a) The cross-sectional area of a wire with a diameter $1.2\ \mathrm{mm}$.

$1.13097336 \times 10^{-6}\ \mathrm{m}^2$

(b) The volume of a Rubik's cube with sides length $12\ \mathrm{cm}$.

$1.728 \times 10^{-3}\ \mathrm{m}^3$

(c) The surface area of the Moon which has a diameter $3745\ \mathrm{km}$.

$4.40609155 \times 10^{13}\ \mathrm{m}^2$

(d) The volume of a baseball with radius $45\ \mathrm{mm}$.

$3.81703507 \times 10^{-4}\ \mathrm{m}^3$

6. Data Handling and Graphical Skills

In an experiment about the properties of light, a set of differently coloured LEDs was used. Data from the experiment is recorded in the table below.

Colour	Wavelength λ / nm	Frequency f / 10^{14} Hz	Minimum pd V_{min} /V
Infrared	940	3.19	0.92
Red	665	4.51	1.54
Orange	625	4.80	1.54
Yellow	595	5.04	1.78
Green	565	5.31	1.87
Blue	470	6.38	2.37

(a) Use the equation $c = f\lambda$ to find the missing values and add them to the table.

(b) Complete the graph on the next page by plotting the missing points and drawing a line of best fit. The line should have as many points above the line as there are below the line.

(c) Calculate the gradient of the line. Use as much of the line as possible.

$$m = \frac{\Delta y}{\Delta x}$$

$$m = \frac{1.48}{3.15} = 0.46984126984$$

(d) The Law of Conservation of Energy tells us that the energy lost by electrons passing through the LED, eV_{min}, is equal to the energy of the photons emitted by the LED, hf.

$$eV_{min} = hf$$

Where e is 1.6×10^{-19} C and h is the Planck constant. On our graph, we can see that V_{min} is on the y-axis and f is on the x-axis. Now compare this equation to the equation for a straight line:

$$y = mx + c$$

Replacing y and x with $Vmin$ and f gives us:

$$V_{min} = mf$$

Compare this to the original equation:

$$eV_{min} = hf$$

Which combination of quantities is the gradient, m, equal to? Use this and your answer to part (c) to find a value for Planck's constant, h.

$$m = \frac{V_{min}}{f}$$

$$h = m \cdot e \cdot (accountancy\ for\ 10^{14}\ \text{Hz})$$

$$h = 0.46984126984 \times (1.6 \times 10^{-19}) \times (10^{-14}) = 7.5174603 \times 10^{-34}$$

(e) The commonly used value of h is 6.63×10^{-34} Js. What is the percentage difference between the accepted value and your answer to part (d)?

$$\frac{(7.5174603 \times 10^{-34}) - (6.63 \times 10^{-34})}{(6.63 \times 10^{-34})} \times 100 = 13.3855248869\%$$