OCR A Physics: GCSE → **A Level transition**

Moving from GCSE Science to A Level can be a daunting leap. You'll be expected to remember a lot more facts, equations, and definitions, and you will need to learn new maths skills and develop confidence in applying what you already know to unfamiliar situations.

This worksheet aims to give you a head start by helping you to understand and practice of some of the maths skills you'll need.

We also recommend you watch the documentary "Atom: Clash of Titans" presented by Jim Al-Khalili. It gives insights into how early physicists had to create a whole new science that underpins the whole of physics and chemistry today. Please follow this YouTube link: https://www.youtube.com/watch?v=GOJFznzSZhM

Foundations of Physics

Learn the answers to the questions below then cover the answers column with a piece of paper and write as many answers as you can. Check and repeat.

What is a physical quantity?	a property of an object or of a phenomenon that can be measured
What are the S.I. units of mass, length, and time?	kilogram (kg), metre (m), second (s)
What base quantities do the S.I. units A, K, and mol represent?	current, temperature, amount of substance
List the prefixes, their symbols and their multiplication factors from pico to tera (in order of increasing magnitude)	pico (p) 10^{-12}, nano (n) 10^{-9}, micro (μ) 10^{-6}, milli (m) 10^{-3}, centi (c) 10^{-2}, deci (d) 10^{-1}, kilo (k) 10^3, mega (M) 10^6, giga (G) 10^9, tera (T) 10^{12}
What is a scalar quantity?	a quantity that has magnitude (size) but *no* direction
What is a vector quantity?	a quantity that has magnitude (size) *and* direction
What are the equations to resolve a force, *F*, into two perpendicular components, F_x and F_y?	$F_x = F \cos \theta$ $F_y = F \sin \theta$
What is the difference between distance and displacement?	distance is a scalar quantity displacement is a vector quantity
What does the Greek capital letter Δ (delta) mean?	'change in'
What is the equation for average speed in algebraic form?	$v = \dfrac{\Delta x}{\Delta t}$
What is instantaneous speed?	the speed of an object over a very short period of time
What does the gradient of a displacement–time graph tell you?	velocity
How can you calculate acceleration and displacement from a velocity–time graph?	acceleration is the gradient displacement is the area under the graph
Write the equation for acceleration in algebraic form.	$a = \dfrac{\Delta v}{\Delta t}$
What do the letters *suvat* stand for in the equations of motion?	*s* = displacement, *u* = initial velocity, *v* = final velocity, *a* = acceleration, *t* = time taken
Write the four *suvat* equations.	$v = u + at$ $\qquad\qquad s = ut + \dfrac{1}{2}at^2$ $s = \dfrac{1}{2}(u+v)t$ $\qquad\qquad v^2 = u^2 + 2as$

Define *stopping distance*	the total distance travelled from when the driver first sees a reason to stop, to when the vehicle stops
Define *thinking distance*	the distance travelled between the moment when you first see a reason to stop to the moment when you use the brake
Define *braking distance*	the distance travelled from the time the brake is applied until the vehicle stops
What does *free fall* mean?	when an object is accelerating under gravity with no other force acting on it

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Maths skills

1 Measurements

1.1 Base and derived SI units

Units are defined so that, for example, every scientist who measures a mass in kilograms uses the same size for the kilogram and gets the same value for the mass. Scientific measurement depends on standard units – most are *Système International* (SI) units. Every measurement must give the unit to have any meaning. You should know the correct unit for physical quantities.

Base units

Physical quantity	Unit	Symbol
length	metre	m
mass	kilogram	kg
time	second	s

Physical quantity	Unit	Symbol
electric current	ampere	A
temperature difference	Kelvin	K
amount of substance	mole	mol

Derived units

Example:

$$\text{speed} = \frac{\text{distance travelled}}{\text{time taken}}$$

If a car travels 2 metres in 2 seconds:

$$\text{speed} = \frac{2\,\text{metres}}{2\,\text{seconds}} = 1\frac{m}{s} = 1\,m/s$$

This defines the SI unit of speed to be 1 metre per second (m/s), or $1\ m\,s^{-1}$ ($s^{-1} = \frac{1}{s}$).

Practice questions

1   Complete this table by filling in the missing units and symbols.

Physical quantity	Equation used to derive unit	Unit	Symbol and name (if there is one)
frequency	period^{-1}	s^{-1}	Hz, hertz
volume	length^3		–
density	mass ÷ volume		–
acceleration	velocity ÷ time		–
force	mass × acceleration		
work and energy	force × distance		

1.2 Significant figures

When you use a calculator to work out a numerical answer, you know that this often results in a large number of decimal places and, in most cases, the final few digits are 'not significant'. It is important to record your data and your answers to calculations to a reasonable number of significant figures. Too many and your answer is claiming an accuracy that it does not have, too few and you are not showing the precision and care required in scientific analysis.

Numbers to 3 significant figures (3 s.f.):

<u>3.62</u>   <u>25.4</u>   <u>271</u>   0.0<u>147</u>   0.<u>245</u>   <u>39 4</u>00

(notice that the zeros before the figures and after the figures are *not* significant – they just show you how large the number is by the position of the decimal point).

Numbers to 3 significant figures where the zeros *are* significant:

<u>207</u>   <u>405</u>0   <u>1.01</u> (any zeros between the other significant figures *are* significant).

Standard form numbers with 3 significant figures:

9.42×10^{-5} 1.56×10^{8}

If the value you wanted to write to 3.s.f. was 590, then to show the zero was significant you would have to write:

590 (to 3.s.f.) or 5.90×10^{2}

Practice questions

2   Give these measurements to 2 significant figures:
    a 19.47 m   **b** 21.0 s   **c** 1.673×10^{-27} kg   **d** 5 s

3   Use the equation:

$$resistance = \frac{potential\ difference}{current}$$

    to calculate the resistance of a circuit when the potential difference is 12 V and the current is 1.8 mA. Write your answer in kΩ to 3 s.f.

1.3 Uncertainties

When a physical quantity is measured there will always be a small difference between the measured value and the true value. How important the difference is depends on the size of the measurement and the size of the uncertainty, so it is important to know this information when using data.

There are several possible reasons for uncertainty in measurements, including the difficulty of taking the measurement and the resolution of the measuring instrument (i.e. the size of the scale divisions).

For example, a length of 6.5 m measured with great care using a 10 m tape measure marked in mm would have an uncertainty of 2 mm and would be recorded as 6.500 ± 0.002 m.

It is useful to quote these uncertainties as percentages.

For the above length, for example,

$$percentage\ uncertainty = \frac{uncertainty}{measurement} \times 100$$

$percentage\ uncertainty = \dfrac{0.002}{6.500} \times 100\% = 0.03\%$. The measurement is 6.500 m ± 0.03%.

Values may also be quoted with absolute error rather than percentage uncertainty, for example, if the 6.5 m length is measured with a 5% error, the absolute error = 5/100 × 6.5 m = ±0.325 m.

Practice questions

4   Give these measurements with the uncertainty shown as a percentage (to 1 significant figure):

    a 5.7 ± 0.1 cm   **b** 450 ± 2 kg   **c** 10.60 ± 0.05 s   **d** $366\,000 \pm 1000$ J

5   Give these measurements with the error shown as an absolute value:

    a 1200 W $\pm 10\%$ **b** $330\,000\ \Omega \pm 0.5\%$

6   Identify the measurement with the smallest percentage error. Show your working.

    A 9 ± 5 mm   **B** 26 ± 5 mm   **C** 516 ± 5 mm   **D** 1400 ± 5 mm

2 Standard form and prefixes

When describing the structure of the Universe you have to use very large numbers. There are billions of galaxies and their average separation is about a million light years (ly). The Big Bang theory says that the Universe began expanding about 14 billion years ago. The Sun formed about 5 billion years ago. These numbers and larger numbers can be expressed in standard form and by using prefixes.

2.1 Standard form for large numbers

In standard form, the number is written with one digit in front of the decimal point and multiplied by the appropriate power of 10. For example:

- The diameter of the Earth, for example, is 13 000 km.

  13 000 km = $1.3 \times 10\,000$ km = 1.3×10^4 km.

- The distance to the Andromeda galaxy is 2 200 000 light years = $2.2 \times 1\,000\,000$ ly = 2.2×10^6 ly.

2.2 Prefixes for large numbers

Prefixes are used with SI units (see Topic 1.1) when the value is very large or very small. They can be used instead of writing the number in standard form. For example:

- A kilowatt (1 kW) is a thousand watts, that is 1000 W or 10^3 W.
- A megawatt (1 MW) is a million watts, that is 1 000 000 W or 10^6 W.
- A gigawatt (1 GW) is a billion watts, that is 1 000 000 000 W or 10^9 W.

Prefix	Symbol	Value
kilo	k	10^3
mega	M	10^6

Prefix	Symbol	Value
giga	G	10^9
tera	T	10^{12}

For example, Gansu Wind Farm in China has an output of 6.8×10^9 W. This can be written as 6800 MW or 6.8 GW.

Practice questions

1   Give these measurements in standard form:
    a 1350 W   **b** 130 000 Pa   **c** 696×10^6 s   **d** 0.176×10^{12} C kg^{-1}

2   The latent heat of vaporisation of water is 2 260 000 J/kg. Write this in:
    a J/g   **b** kJ/kg   **c** MJ/kg

2.3 Standard form and prefixes for small numbers

At the other end of the scale, the diameter of an atom is about a tenth of a billionth of a metre. The particles that make up an atomic nucleus are much smaller. These measurements are represented using negative powers of ten and more prefixes. For example:

- The charge on an electron = 1.6×10^{-19} C.
- The mass of a neutron = $0.016\,75 \times 10^{-25}$ kg = 1.675×10^{-27} kg (the decimal point has moved 2 places to the right).
- There are a billion nanometres in a metre, that is 1 000 000 000 nm = 1 m.
- There are a million micrometres in a metre, that is 1 000 000 μm = 1 m.

Prefix	Symbol	Value
centi	c	10^{-2}
milli	m	10^{-3}
micro	μ	10^{-6}

Prefix	Symbol	Value
nano	n	10^{-9}
pico	p	10^{-12}
femto	f	10^{-15}

Practice questions

3 Give these measurements in standard form:
   a 0.0025 m   **b** 160×10^{-17} m   **c** 0.01×10^{-6} J   **d** 0.005×10^{6} m   **e** 0.00062×10^{3} N

4 Write the measurements for question 3a, c, and d above using suitable prefixes.

5 Write the following measurements using suitable prefixes.
   a a microwave wavelength = 0.009 m
   b a wavelength of infrared = 1×10^{-5} m
   c a wavelength of blue light = 4.7×10^{-7} m

2.4 Powers of ten

When multiplying powers of ten, you must *add* the indices.

So 100 × 1000 = 100 000 is the same as $10^2 \times 10^3 = 10^{2+3} = 10^5$

When dividing powers of ten, you must *subtract* the indices.

So $\dfrac{100}{1000} = \dfrac{1}{10} = 10^{-1}$ is the same as $\dfrac{10^2}{10^3} = 10^{2-3} = 10^{-1}$

But you can only do this when the numbers with the indices are the same.

So $10^2 \times 2^3 = 100 \times 8 = 800$

And you can't do this when adding or subtracting.

$10^2 + 10^3 = 100 + 1000 = 1100$

$10^2 - 10^3 = 100 - 1000 = -900$

Remember: You can only add and subtract the indices when you are multiplying or dividing the numbers, not adding or subtracting them.

Practice questions

6 Calculate the following values – read the questions very carefully!

    a $20^6 + 10^{-3}$

    b $10^2 - 10^{-2}$

    c $2^3 \times 10^2$

    d $10^5 \div 10^2$

7 The speed of light is 3.0×10^8 m s^{-1}. Use the equation $v = f\lambda$ (where λ is wavelength) to calculate the frequency of:

    a ultraviolet, wavelength 3.0×10^{-7} m

    b radio waves, wavelength 1000 m

    c X-rays, wavelength 1.0×10^{-10} m.
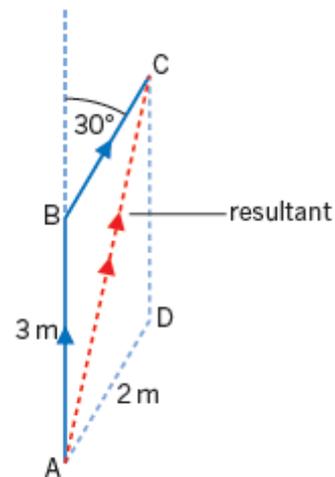
3 Resolving vectors

3.1 Vectors and scalars

Vectors have a magnitude (size) and a direction. Directions can be given as points of the compass, angles or words such as forwards, left or right. For example, 30 mph east and 50 km/h north-west are velocities.

Scalars have a magnitude, but no direction. For example, 10 m/s is a speed.

Practice questions

1 State whether each of these terms is a vector quantity or a scalar quantity: density, temperature, electrical resistance, energy, field strength, force, friction, frequency, mass, momentum, power, voltage, volume, weight, work done.

2 For the following data, state whether each is a vector or a scalar: 3 ms^{-1}, +20 ms^{-1}, 100 m NE, 50 km, −5 cm, 10 km S 30° W, 3×10^8 ms^{-1} upwards, 273 °C, 50 kg, 3 A.

3.2 Drawing vectors

Vectors are shown on drawings by a straight arrow. The arrow starts from the point where the vector is acting and shows its direction. The length of the vector represents the magnitude.

When you add vectors, for example two velocities or three forces, you must take the direction into account.

The combined effect of the vectors is called the resultant.

This diagram shows that walking 3 m from A to B and then turning through 30° and walking 2 m to C has the same effect as walking directly from A to C. AC is the resultant vector, denoted by the double arrowhead.

A careful drawing of a scale diagram allows us to measure these. Notice that if the vectors are combined by drawing them in the opposite order, AD and DC, these are the other two sides of the parallelogram and give the same resultant.

Practice question

3 Two tractors are pulling a log across a field. Tractor 1 is pulling north with force 1 = 5 kN and tractor 2 is pulling east with force 2 = 12 kN. By scale drawing, determine the resultant force.
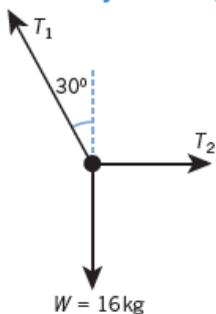
3.3 Free body force diagrams

To combine forces, you can draw a similar diagram to the one above, where the lengths of the sides represent the magnitude of the force (e.g., 30 N and 20 N). The third side of the triangle shows us the magnitude and direction of the resultant force.

When solving problems, start by drawing a free body force diagram. The object is a small dot and the forces are shown as arrows that start on the dot and are drawn in the direction of the force. They don't have to be to scale, but it helps if the larger forces are shown to be larger. Look at this example.

A 16 kg mass is suspended from a hook in the ceiling and pulled to one side with a rope, as shown on the right. Sketch a free body force diagram for the mass and draw a triangle of forces.

Free body force diagram

Triangle of forces
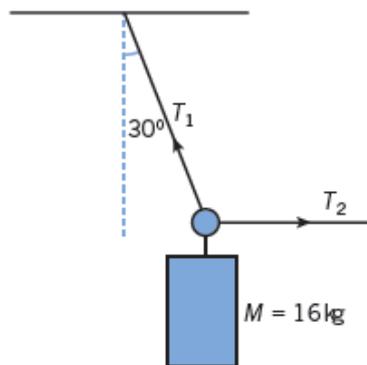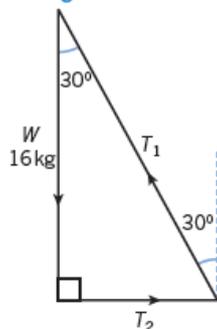
Notice that each force starts from where the previous one ended and they join up to form a triangle with no resultant because the mass is in equilibrium (balanced).

Practice questions

4   Sketch a free body force diagram for the lamp (**Figure 1**, below) and draw a triangle of forces.

5   There are three forces on the jib of a tower crane (**Figure 2**, below). The tension in the cable T, the weight W, and a third force P acting at X.

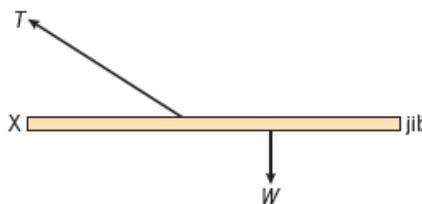The crane is in equilibrium. Sketch the triangle of forces.
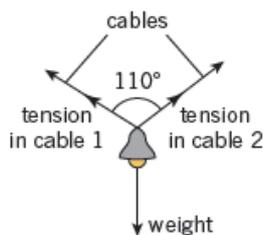
Figure 1

Figure 2

3.4 Calculating resultants

When two forces are acting at right angles, the resultant can be calculated using Pythagoras's theorem and the trig functions: sine, cosine, and tangent.
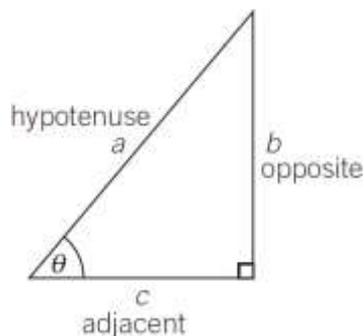
For a right-angled triangle as shown:

$h^2 = o^2 + a^2$

$\sin \theta = \dfrac{o}{h}$

$\cos \theta = \dfrac{a}{h}$

$\tan \theta = \dfrac{o}{a}$

(soh-cah-toa).

Practice questions

6 **Figure 3** shows three forces in equilibrium.

Draw a triangle of forces to find *T* and *α*.

7 Find the resultant force for the following pairs of forces at right angles to each other:

a 3.0 N and 4.0 N   **b** 5.0 N and 12.0 N

Figure 3

4 Rearranging equations

Sometimes you will need to rearrange an equation to calculate the answer to a question. For example, if you want to calculate the resistance *R*, the equation:

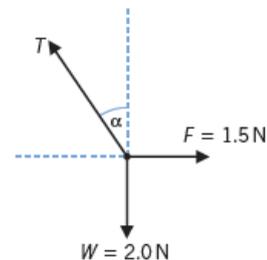potential difference (*V*) = current (*A*) × resistance (Ω)   or   *V* = *I R*

must be rearranged to make *R* the subject of the equation:

$R = \dfrac{V}{I}$

When you are solving a problem:

- Write down the values you know and the ones you want to calculate.

- you can rearrange the equation first, and then substitute the values

    or

- substitute the values and then rearrange the equation

4.1 Substitute and rearrange

A student throws a ball vertically upwards at 5 m s^{-1}. When it comes down, she catches it at the same point. Calculate how high it goes.

step 1: Known values are:

- initial velocity $u = 5.0$ m s^{-1}
- final velocity $v = 0$ (you know this because as it rises it will slow down, until it comes to a stop, and then it will start falling downwards)
- acceleration $a = g = -9.81$ m s^{-2}
- distance $s = ?$

Step 2: Equation:

(final velocity)^2 − (initial velocity)^2 = 2 × acceleration × distance

or $\quad v^2 - u^2 = 2 \times g \times s$

Substituting: $(0)^2 - (5.0$ m s$^{-1})^2 = 2 \times -9.81$ m s$^{-2} \times s$

$0 - 25 = 2 \times -9.81 \times s$

Step 3: Rearranging:

$-19.62\ s = -25$

$s = \dfrac{-25}{-19.62} = 1.27$ m $= 1.3$ m (2 s.f.)

Practice questions

1 The potential difference across a resistor is 12 V and the current through it is 0.25 A. Calculate its resistance.

2 Red light has a wavelength of 650 nm. Calculate its frequency. Write your answer in standard form.

   (Speed of light = 3.0×10^8 m s^{-1})

4.2 Rearrange and substitute

A 57 kg block falls from a height of 68 m. By considering the energy transferred, calculate its speed when it reaches the ground.

(Gravitational field strength = 10 N kg^{-1})

Step 1: $m = 57$ kg $\quad h = 68$ m $\quad g = 10$ N kg^{-1} $\quad v = ?$

Step 2: There are three equations:

$\quad$ PE = $m\,g\,h$ $\quad$ KE gained = PE lost $\quad$ KE = 0.5 $m\,v^2$

Step 3: Rearrange the equations before substituting into it.

$\quad$ As KE gained = PE lost, $m\,g\,h = 0.5\ m\,v^2$

$\quad$ You want to find v. Divide both sides of the equation by 0.5 m:

$$\frac{mgh}{0.5m} = \frac{0.5mv^2}{0.5m}$$

$\quad$ $2\,g\,h = v^2$

$\quad$ To get v, take the square root of both sides: $v = \sqrt{2gh}$

Step 4: Substitute into the equation:

$$v = \sqrt{2 \times 10 \times 68}$$

$$v = \sqrt{1360} = 37 \text{ m s}^{-1}$$

Practice question

3 Calculate the specific latent heat of fusion for water from this data:

$\quad$ 4.03×10^4 J of energy melted 120 g of ice.

$\quad$ Use the equation:

$\quad\quad$ thermal energy for a change in state (J) = mass (kg) × specific latent heat (J kg^{-1})

$\quad$ Give your answer in J kg^{-1} in standard form.

Practice questions

4 Calculate the percentage efficiency of a motor that does 8400 J of work to lift a load.

$\quad$ The electrical energy supplied is 11 200 J.

5 An 850 W microwave oven has a power consumption of 1.2 kW.

$\quad$ Calculate the efficiency, as a percentage.

6 Use your answer to question 4 above to calculate the percentage efficiency of the motor. (The motor, rated at 8.0 kW, lifts a 2500 N load 15 m in 5.0 s.)

7 Determine the time it takes for a 92% efficient 55 W electric motor take to lift a 15 N weight 2.5 m.