Newent Community School

KS5 Physics

Yr 11 Bridging Work

The Purpose of this document is to practice the recommended mathematical skills required to study A Level Physics at Newent Community school.

This is also a practice of the independent working required for students working towards any GCE qualification. Support will be offered for those who struggle, but a worthwhile attempt must first be made.

Skills B10 and B11 ae intentionally not included in this booklet.

Contents

SKILL B1: UNITS, CONVERSION BETWEEN UNITS AND ORDERS OF MAGNITUDE

Part A: Specification ***Overview***

The course will expect you to be able to identify and use appropriate units in calculations involving physical quantities. This skill will be tested throughout every topic in this course.

Part B: Theoretical Overview

International System (SI) of Base Units

SI base units are a set of units of measure. The set of units can then be used to derive all other units from.

When calculating physical quantities in this course you will need to include their units in your final answer. The units will not be given to you and you will be expected to recall the SI base units.

Any calculation involving quantities with units that aren't SI base units will require you to either recall the units or be able to derive them from the SI base units.

The following SI base units and their corresponding physical quantities are given below:

Physical Quantity	SI Base Units	Common Abbreviation of SI Units
Mass	Kilograms	Kg
Time	Seconds	S
Energy	Joules	J
Temperature	Kelvin	K
Length	Metres	M
Current	Amperes	A
Amount of a substance	Moles	Mol

You will be expected to present physical quantities in their SI base units unless specified otherwise. For example, if you are using distance and time to determine velocity, the displacement and the time quantities must be in metres and seconds respectively to perform the calculation, unless stated otherwis

Conversion between units

You will also have to be able to convert between units. You may potentially be given a unit in different orders of magnitude and need to convert back to the SI unit in order to perform the calculation. Prefixes can be used to convert between units in different orders of magnitude. A prefix is the symbol which is used before the unit to let you know the order of magnitude.

Prefix	Order of magnitude
Pico (p)	$\times \mathbf{10^{-12}}$
Nano (n)	$\times \mathbf{10^{-9}}$
Micro (μ)	$\times \mathbf{10^{-6}}$
Mili (m)	$\times \mathbf{10^{-3}}$
Centa (c)	$\times \mathbf{10^{-2}}$
Deci (d)	$\times \mathbf{10^{-1}}$
Kilo (k)	$\times \mathbf{10^{3}}$
Mega (M)	$\times \mathbf{10^{6}}$
Giga (G)	$\times \mathbf{10^{9}}$
Tera (T)	$\times \mathbf{10^{12}}$

Part C: Worked Example

A family car travels 8.00 km in 10 minutes. The velocity of the car is given by the equation $v = \frac{s}{t}$.

Calculate the velocity of the car during the 10 minutes, giving your answer in SI units.

Solution:

1. First, you will have to notice that the time and the displacement are not in their SI units and therefore you will have to convert the units before performing the calculation:

   $s = 8.00\ \text{km}$

   $\text{k} = \times 10^3$

   therefore, in SI base units, $s = 8.00\times10^3\ \text{m}$

   $t = 10\ \text{minutes}$

   1 minute = 60 seconds

   therefore, in SI base units, $t = (10\times60) = 600\ \text{s}$

2. Now all the quantities used in the calculation are in SI units and the calculation can be performed:

   $v = \frac{s}{t}$

   $v = \frac{8\times10^3}{600}$

   $v = 13.3\ \text{ms}^{-1}$

The SI base units for v are:
$v = \frac{s}{t}$ $\quad v = \frac{\text{m}}{\text{s}}$
$v = \text{ms}^{-1}$

Part D: Practice Questions

1. Which of the following is the SI base unit for energy?

A. J
B. kg
C. K
D. M

2. State the SI base units for the following physical quantities:

a) Mass
b) Temperature
c) Potential difference
d) Resistance

3. The National Grid supplies electricity to our homes.

The cables used to transmit electricity lose around 188 kW of power due to heating in the cables.

Convert the power loss into watts (W).

4. A cylindrical canister is used in a physics investigation into the properties of gases.

The physicist needs to calculate the volume of the cylinder to carry out the investigation.

- The radius of the cylinder's circular face is 200 cm and it has height 1400 cm.

- The volume for a cylinder is given by the equation $V = \pi r^2 h$.

What is the volume of the cylinder in cubic metres?

SKILL B2: USE AND CALCULATE QUANTITIES IN DIFFERENT FORMS

Part A: Specification Overview

The exam board will expect you to be able to identify and work with expressions in decimal and standard form. You will be tested on your ability to use, calculate and present physical quantities in the two different forms. This knowledge and skill will be tested throughout each of the topics for this course.

Part B: Theoretical Overview

Decimal Form:

A decimal is a fraction written in an alternative form. It can be identified by its decimal dot.

An example of a decimal form would be:

3.4

where the 3 is in the units column and the 4 is in the 10^{th}s column. It can then be read as '3 point 4' or '3 and 4 10^{th}s'.

Standard Form:

The number N can be said to be in standard form if it is written in the following format:

$$N = S \times 10^x.$$

S represents a number and x, if positive, represents how many times the number N has been multiplied by 10 and, if negative, how many times the number N has been divided by 10.

Standard form is used as a more convenient way of representing numbers that are either very large or very small.

For example:

- The number 147,000,000,000 could be written more conveniently in its standard form, 1.47×10^{11}
- The number 0.00000000236 could be written more conveniently in its standard form, 2.36×10^{-9}

You will be expected to recognise and convert numbers into these two forms and then use them in calculations.

To convert to standard form:

1. Identify the first non-zero digit of your number and place a decimal point after it.

   e.g. 70,000

   7.
2. Then determine how many times your first digit has been multiplied by 10 to get back to you original number.

   e.g. $7\times10\times10\times10\times10 = 70\ 000$

   Therefore, 7 has been multiplied by 10 four times.
3. To write it in standard form, you take the number of times your digit has been multiplied by 10 and multiply your digit by 10 to the power of this:

e.g. 7×10^4
The same method works for a decimal.

To convert a decimal to standard form:

1. Identify the first non-zero digit of your decimal and place a decimal after it (making sure you include any non-zero terms after it also).
   e.g 0.0045
   4.5
2. Then determine how many times our first non-zero digit has been divided by 10 to get back to your original number:
   $4.5 \div 10 \div 10 \div 10 = 0.0045$
   Therefore, 4.5 has been divided by 10 three times.
3. To write the decimal in standard form, you take the number of times your digit has been divided by 10 and multiply your digit by 10 to the power of this number.
   In this case, however, we include a minus to indicate we have divided by 10 instead of multiplied like before.
   e.g 4.5×10^{-3}

Part C: Worked Example

1. The mass of the Earth is $M = 5\ 972\ 000\ 000\ 000\ 000\ 000\ 000\ 000$ kg and its radius is $r = 6.37 \times 10^6$ km.

The gravitational constant G is given by $G = 6.67 \times 10^{-11}\ \text{Nm}^2\ \text{kg}^{-2}$.

The equation for the gravitational potential is $U = -\dfrac{GM}{r}$.

a) Write the Earth's mass, *M*, in standard form.

b) Calculate the gravitational potential at Earth's surface, ensuring all your values are in standard form, including your answer.

Solution:

1. a) $M = 5\ 972\ 000\ 000\ 000\ 000\ 000\ 000\ 000$

$M = 5.97 \times 10 \times \ldots$

$\ldots \times 10 \times 10 \times 10 \times 10$

5.97 has been multiplied by 10 twenty-four times

$M = 5.97 \times 10^{24}$ kg

b) $U = -\dfrac{GM}{r}$

$$U = -\frac{(6.67 \times 10^{-11}) \times \left(5.97 \times 10^{24}\right)}{(6.37 \times 10^6)}$$

$$U = -\frac{3.98 \times 10^{14}}{6.37 \times 10^6}$$

$U = -62511616.95$ J

$U = -62522743.68$

$6.25 \times 10 \times 10 \times 10 \times 10 \times 10 \times 10 \times 10 \times 10 \times 10$

6.25 has been multiplied by 10 nine times

$U \approx -6.25 \times 10^9$ J

Part D: Practice Questions

1. Write the following numbers in standard form:

a) 2,568,700

b) 0.00236

c) 369

d) 0.0581

2. Convert the following numbers out of standard form:

a) 4.78×10^7

b) 1.2×10^{-3}

c) 763×10^2

d) 6.33×10^{-14}

3. The kinetic energy of an object is determined by the following equation:

$$E_k = \frac{1}{2}mv^2$$

A 8.30×10^3 kg car travels with velocity of 11.0 ms^{-1}.

a) Write the mass of the car as a whole number.

b) Calculate the kinetic energy of the car travelling at 11.0 ms^{-1}, giving your answer in standard form.

SKILL B3: ESTIMATION

Part A: Specification Overview

This Physics course will require making appropriate estimates of physical quantities and using them within your calculations. Additionally, your estimation skills will be further tested in experimental data questions when you will be expected to estimate the effects of varying experimental variables.

This skill is tested throughout the course.

Part B: Theoretical Overview

In the course you might not always be provided with the numerical values for physical quantities required for a calculation. The exam board, in this case, would then expect you to demonstrate a sound understanding of the course by making appropriate estimates of quantities to use in your calculation.

The exam board won't expect you to be able to estimate a physical quantity to numerous decimal places.

Estimates of typical quantities are in the table below:

Quantity	Estimate
Mass of a car	1,000 kg
Mass of an adult	70–80 kg
Weight of an adult	700–800 N
Height of a man	2 m
Speed of sound	300 $\mathrm{ms^{-1}}$
Pressure of the atmosphere	100,000 Pa
Density of water	1,000 $\mathrm{kg\,m^{-3}}$
Speed on motorway	30–40 $\mathrm{ms^{-1}}$
Speed of plane	300 $\mathrm{ms^{-1}}$
Power of a car	60 kW
Power of a person	100 W
Distance to Sun	150,000,000 km
Distance to Moon	400,000 km
Mass of Earth	6×10^{24} kg
Radius of Earth	6,000 km

Part C: Worked Example

1. The equation for gravitational potential energy is:

$$E_p = mgh$$

where m is the mass of the object, g is the acceleration due to gravity, and h is the height the object is lifted through.
The gravitational potential energy is defined as the energy stored by an object that has been lifted through a height h.
A diver is standing at the end of a 5 m diving board. The acceleration due to gravity $g = 9.81\ \text{ms}^{-1}$

a) Estimate the mass of an average man

b) Calculate the gravitational potential energy E_p

c) Predict what would happen to your answer to (b) if the diver was standing at the end of a 10 m board instead.

Solution:

1. a) 70–80 kg

b) $E_p = mgh$

$E_p = (70-80)\times 9.81\times 5$

$E_p = 3430 - 3924\ \text{J}$

c) Since $E_p \propto h$, if h doubles then we can estimate that E_p will also double in magnitude.

Part D: Practice Questions

1. A car is travelling for 10,000 seconds at an average speed on a motorway.
The equation to determine the distance travelled by the car is $d = s\times t$.
Estimate how far the car has travelled in 10,000 seconds.

2. Two planes are travelling with average speed to their respective destinations.
Plane 1 travels for 10,800 seconds and Plane 2 travels for 14,400 seconds.
Estimate the difference between the distances travelled by Plane 1 and Plane 2.

Note: $d = s\times t$

3. The gravitational potential of a planetary object is:

$$V = -\frac{GM}{r}$$

where M is the mass of the planetary object, r is the distance from its centre to a point in space and G is a gravitational constant 6.67×10^{-11}.

Estimate the gravitational potential at the Earth's surface (the distance r will therefore be the distance from the centre of Earth to its surface).

PART 2 MATHEMATICS FOR PHYSICS

SKILL B4: SIGNIFICANT FIGURES

Part A: Specification Overview

The specification states that you should be able to use an appropriate number of significant figures when presenting numbers or measured values.

Specifically, they want to see you demonstrating ability to:

- present calculations to an appropriate number of significant figures given variables in varying numbers of significant figures
- demonstrate that calculated quantities can only be presented to the limits of the least accurate measured value

Part B: Theoretical Overview

Significant figures are used to round numbers. When calculating quantities it isn't always necessary to provide a detailed value for a quantity, and sometimes an approximation is all that is needed. For these cases you will need to use your knowledge of significant figures.

The significant figure of a value is best demonstrated with an example:

23,569	1st significant figure = 2 2nd significant figure = 3 3rd significant figure = 5 and so on
76.5	1st significant figure = 7 2nd significant figure = 6 3rd significant figure = 5
801	1st significant figure = 8 2nd significant figure = 0 3rd significant figure = 1
0.004	1st significant figure = 4

You should start to see the pattern, and also realise that the most significant figure is always the first non-zero term. If a zero appears in the value between numbers then it counts as a significant figure because of its value as a placeholder.

If you are told to provide a measured quantity to x significant figures you will need to carry out the following steps:

1. Identify your x^{th} significant figure.
2. Round up if the number after the x significant figure is 5 or above, or don't round up if the number after the significant figure is 4 or below.
3. Then set all the numbers that follow the significant figure to zero.

For example, if you were given $F = 38.37654 \text{ N}$, you might not need to know the value of force to such an accurate degree and might be asked to round it to 3 significant figures:

1. The 3rd significant figure is 3.
2. The number after the significant figure is 7; therefore, you will need to round up.
3. The number to 3 significant figures will then be 38.40000, but since the zeros are after the decimal we can simply write 38.4 N.

Note: When rounding a measured value to significant figures you cannot have more significant figures (a more accurate measured value) than the values you are given to calculate the measured value.

Part C: Worked Example

1. Write 50,214,235.3256 to 4 significant figures.

2. A group of engineers are attempting to fix the cables on a suspension bridge. In order to ensure the bridge is stable and safe they need to determine the stress acting on the cables.

The equation for stress is: $\sigma = \frac{F}{A}$

where σ represents stress, F represents the force exerted on the object and A is the cross–sectional area of the object.

The group of engineers know that force acting on one cable is 85,369.234 N. The cross-sectional area of the cable is 0.690 m^2.

a) Calculate the stress felt by one cable.

b) Explain why the answer cannot be presented as $\sigma = 123723.5275$.

c) Write your answer to (a) to 3 significant figures.

Solution:

1. 50,210,000

2. a) $\sigma = \frac{F}{A}$

$$\sigma = \frac{85369.234}{0.69}$$

$$\sigma = 123723.5275$$

$$\sigma = 123723.53$$

b) Since the calculated result σ cannot be more accurate than the most accurate value (0.690 m^2) used in the calculation, the answer can only be given to 3 significant figures.

c) 124,000

Part D: Practice Questions

1. Which of the following numbers is 345,700 written to 2 significant figures?

A. 340,000

B. 34

C. 350,000

D. 345,700

2. Write the following numbers to 3 significant figures:

a) 30,501

b) 567,843.22

c) 0.0023695

3. A sound engineer checking the electrical supply to a speaker system measures a current through the cables of 1.60 A and a potential difference of 2.63 V across them. From these measured values, the engineer calculates the resistance to be 1.64375 Ω. What is wrong with her conclusion?

4. The Space Shuttle requires an enormous force of 10,500,000 million newtons to launch into space. The shuttle has a mass of 2,220,000 kg.

Determine the acceleration $\left(a = \frac{F}{m} \right)$ of the shuttle as it launches into space.

Write your value to an appropriate number of significant figures.

SKILL B5: MEAN VALUE

Part A: Specification Overview

You will need to be able to calculate the mean of experimental values obtained from repeated measurements.

This skill can be tested within any of the course's topics.

Part B: Theoretical Overview

The mean value represents the average of the range of measurements.

It is good experimental practice to take repeated measurements of a value so as to achieve the most accurate measurement of the value by reducing the contribution of errors in the experiment. A mean value (or an average value) would then be required if the measured value was to be used to determine other physical quantities involved in the experiment.

Let's say you had N measurements. The equation for calculating the mean is as follows:

$$mean = \frac{x_1 + x_2 + x_3 + ... + x_N}{N}$$

where $x_1, x_{2,}, x_3, ..., x_N$ are the N measurements

Part C: Worked Example

A Year 11 physics pupil is carrying out an experiment on various electrical components. The pupil measures the resistance of a resistor. The student repeats the measurement to obtain 10 values:

Resistance (Ω)									
r_1	r_2	r_3	r_4	r_5	r_6	r_7	r_8	r_9	r_{10}
2.43	2.24	2.41	2.36	2.33	2.27	2.42	2.56	2.32	2.29

Calculate the mean value for resistance of the pupil's measured values.

Solution:

N = the number of measured values = 10

$$mean = \frac{r_1 + r_2 + r_3 + r_4 + r_5 + r_6 + r_7 + r_8 + r_9 + r_{10}}{N}$$

$$mean = \frac{2.43 + 2.24 + 2.41 + 2.36 + 2.33 + 2.27 + 2.42 + 2.56 + 2.32 + 2.29}{10}$$

$$mean = \frac{23.63}{10}$$

$$mean = 2.363$$

$$mean = 2.36$$

Part D: Practice Questions

1. A physicist obtains the following measured values for the temperature of liquid nitrogen in kelvin:

T_1	T_2	T_3	T_4	T_5
77.0	76.0	75.0	78.0	77.0

a) Explain how the physicist could determine the average value obtained for temperature.
b) Calculate the mean value for the temperature of liquid nitrogen.

2. The transport department released statistics on the velocity of cars outside schools. A sample size of five different cars is given below:

Car 1	Car 2	Car 3	Car 4	Car 5
30.0 mh^{-1}	40.0 mh^{-1}	20.0 mh^{-1}	22.0 mh^{-1}	25.0 mh^{-1}

Calculate the mean value for the velocity from this sample.

SKILL B6: USE CALCULATOR TO HANDLE SIN, COS AND TAN

Part A: Specification Overview

The exam board expect you, throughout the course, to be able to use your calculator to deal with trigonometric functions ($\sin x, \cos x$ and $\tan x$). You will be tested on your ability to use these functions when expressed in both degrees and radians.

Using your calculator to handle the trigonometric functions will be assessed predominantly when working with vectors and projectile motion, but expect it to also appear at various points during the course.

Part B: Theoretical Overview

When working with calculations involving trigonometric functions always read whether the question is asking you to work in degrees or radians. Ensure you set your calculator to the correct setting accordingly before continuing with the calculation.

Part C: Worked Example

1. **During an investigation into the critical angles of different materials it was found that the critical angle of Material 1 was 39.9°.**
   The equation relating the critical angle and the refractive index of a material is given below:

$$\sin C = \frac{1}{n}$$

where C is the critical angle and n is the refractive index of the material.

a) Use this equation to determine the refractive index n of Material 1.

The refractive index of Material 2 was known to be 1.33.

b) Calculate the critical angle of Material 2.

Solution:

a) $\sin C = \frac{1}{n}$

$\sin 39.9 = \frac{1}{n}$

$n = \frac{1}{\sin 39.9}$

To evaluate n, follow the next steps using the buttons on your calculator:

1 **÷** **sin** 3 **=**

Following those steps will display an answer of 1.56 on your calculator display window.

Therefore,

$n = 1.56$

Note: Make sure your calculator is set to degrees

b) $\sin C = \frac{1}{n}$

$\sin C = \frac{1}{1.33}$

$\sin C = 0.750$

$C = \sin^{-1}(0.750)$

To evaluate C, proceed with the following steps, using the buttons on your calculator:

shift **sin** 0.75 **=**

Following those steps will display the answer 48.6 on your calculator display window.

Therefore,

$C = 48.6°$

Part D: Practice Questions

1. Determine the solutions to the following equations:

a) $\sin 0.56$

b) $\cos 78$

c) $\tan 14$

2. Determine x in the following equations:

a) $\tan x = 0.300$

b) $\cos x = 0.290$

c) $\sin x = 0.830$

3. The displacement of an object displaying simple harmonic motion can be found using the equation:

$$x = A\cos \omega t$$

where x is the displacement, A is amplitude, ω is angular frequency and t is the time of oscillation.

A bungee jumper will undergo simple harmonic motion during their jump.

The angular frequency of the jumper is 2.30 $\text{rad}\,\text{s}^{-1}$ and its amplitude 10.3 m.

Calculate the displacement of the jumper after 500 seconds.

SKILL B7: USE CALCULATOR TO WORK WITH POWER FUNCTIONS

Part A: Specification Overview

You will be expected to determine and use power functions during calculations of physical quantities. This skill will be tested in various topics throughout this course; however, it will be particularly relevant in kinetic energy problems, as well as elastic potential energy problems.

Part B: Theoretical Overview

A power function is any function written in the following form:

$$y = x^n$$

where n is any real constant and y and x are two variables.

For example, the following function can be defined as a power function:

$$y = x^5$$

The above function can be read as '*y is equal to x to the power of 5'.*

It is simple to determine the value of the variable y if you are given the value of the variable x.

For example, if $x = 4$, then

$$y = x^5$$
$$y = (4)^5$$
$$y = 4 \times 4 \times 4 \times 4 \times 4$$
$$y = 1024$$

Alternatively, you can also determine the variable x if you are given the value for the variable y. However, this proves to be a little harder as you will have to invert the power function.

For example if $y = 32$, then

$$y = x^5$$
$$32 = x^5$$
$$x = \sqrt[5]{32}$$
$$x = 2$$

The second last line can be read as, '*The 5th root of 32'.*

To find the 5th root you are essentially looking for a number that has been multiplied by itself 5 times to equal 32. The calculation can be done two ways:

- Using the root button on your calculator to enter the equation
- From recall of your knowledge of roots

The last method will only be applicable to easy roots such as $\sqrt{16}$. This can be read as the square root of 16, which essentially means you are looking for a number that equals 16 when multiplied by itself.

Part C: Worked Example

1. **The equation relating x and y is given by $x = y^3 + 1$**
   Calculate the value of x when $y = 4$
2. **Halley's comet is in orbit round the Sun. The comet reaches its maximum orbital speed when closest to the Sun. The maximum speed of Halley's comet is approximately $3.68 \times 10^4\ \text{ms}^{-1}$.**
   The mass of Halley's comet is approximately 2.20×10^{14} kg.
   The equation for kinetic energy of a moving object is given by:

$$E_k = \frac{1}{2}mv^2$$

   where m is the mass of the object and v is the speed of the object.
   a) Calculate the kinetic energy (E_k) of Halley's comet when it is closest to the Sun.
   The kinetic energy of another comet is calculated to be $E_k = 1.37 \times 10^{22}$ J and has a mass of 1.30×10^{14} kg
   b) Show by calculation whether this comet has a lower or greater maximum speed than Halley's comet when it is closest to the Sun in its orbit.

Solution:

1. $x = y^3 + 1$

$x = (4)^3 + 1$

To evaluate x, proceed with the following steps using the buttons on your calculator:

4 **x□** 3 **+** 1

Following the steps above will display an answer of 65 in your calculator's display box.

Therefore,

$x = 65$

2. a) $x = y^3 + 1$

$E_k = \frac{1}{2} \times (2.20 \times 10^{14}) \times (3.68 \times 10^4)^2$

$E_k = 1.49 \times 10^{23}$ J

b) $E_k = \frac{1}{2}mv^2$

$1.37 \times 10^{22} = \frac{1}{2} \times (1.30 \times 10^{14}) \times v^2$

$v = \sqrt{\dfrac{1.37 \times 10^{22}}{\frac{1}{2} \times 1.30 \times 10^{14}}}$

$v = 1.45 \times 10^4\ \text{ms}^{-1}$

The velocity is less than the velocity of Halley's comet.

Part D: Practice Questions

1. The equation relating a and b is given by $a = b^2$.

If $b = 3$, calculate the value for a.

2. When a spring is stretched from its rest position it holds elastic potential energy (E).

The equation for calculate elastic potential is:

$$E = \frac{1}{2}kx^2$$

Calculate the elastic potential (E) of a spring with a spring constant $k = 2.2 \times 10^4\ \text{Nm}^{-1}$ when it is stretched (x) by 0.020 m.

3. A group of Year 11 physicists were conducting experiments into the electrical properties of circuits. The group measured the potential difference (V) across a 10 Ω resistor to be 2.4 V.

The equation for calculating the power is given by:

$$P = \frac{V^2}{R}$$

where P is the power, V is the potential difference and R is the resistance.

Calculate the power of the resistor.

4. A car accelerates (a) at 2.8 ms^{-1} and covers a distance (s) of 15.8 m. If the car was initially travelling at a velocity (u) of 2.3 ms^{-1}, use the equation $v^2 = u^2 + 2as$ to find what the final velocity (v) of the car will be after it accelerates over this distance.

SKILL B8: CHANGING THE SUBJECT OF THE FORMULA

Part A: Specification Overview

Your ability to change the subject of a formula is essential for success in the Physics course.

The skill is continually assessed throughout each and every topic. A competent grasp of the skill will aid your speed and accuracy in answering questions.

The exam board require you to be able to change the subject of a formula to determine unknown quantities in the formula.

Part B: Theoretical Overview

To change the subject of the formula you will use inverse operations to manipulate the formula and make the quantity you are trying to find the subject.

An example would be the equation for a straight line:

$$y = mx + c$$

You may already know a point (x, y) and the gradient m of the line, and would like to find the y-intercept c.

In its current form, the equation is not useful as a means to determine the value c. The equation needs to to be rearranged so c is the subject:

1. Initially you would want to bring all the variables that aren't c to one side of the equation using inverse operations.
   In this case it would mean taking away the term mx:

$$y - mx = c$$

2. If the unknown variable is still not the subject of the formula, further inverse operations would have to be carried out to remove it from the other variables.
   In our case, c is the subject of the formula and we have now done enough:

$$c = y - mx$$

   The equation can now be used as a tool to determine the value for the unknown variable c.

Note: If the unknown variable is still not the subject of the formula, further inverse operations would have to be carried out to get it by itself.

Part C: Worked Example

Particle accelerators are used by hospitals in radiotherapy treatment to cure cancer. Particles are accelerated between charged plates that control their direction.

The equation relating the work done on the particle and the kinetic energy of the particle is given below:

$$eV = \frac{1}{2}mv^2$$

where e is the charge of the particle, V is the potential of the charged plates, m is the mass of the particle and v is the velocity of the particle.

To ensure accelerators are operating correctly, a medical physicist wants to know the velocity v of the particles.

Rearrange the formula so that it is in a more appropriate form to determine the velocity of the particle.

Solution:

We would need to make v the subject of the formula:

1. To make v the subject, we need to move all other variables to one side of the equation:
   - v is initially divided by 2, and therefore to move 2 to the other side of the equation we use the inverse operation to multiply each side by 2

$$2eV = mv^2$$

   - v is multiplied by m, and therefore to move m to the other side of the equation we use the inverse operation of dividing each side of the equation by m

$$\frac{2eV}{m} = v^2$$

2. All the other variables are now on one side, but v is still not by itself; therefore, we must carry out a further inverse operation:
   - v is squared in its current form, and therefore to get v by itself we have to square root both sides

$$v = \sqrt{\frac{2eV}{m}}$$

Now v is the subject of the formula and the formula is now in a form that can be easily used to determine the velocity of the particles.

Part D: Practice Questions

1. Given the following equation:

$$tx = 2 + p$$

Which of the following answers illustrates the subject of the equation being changed to x?

A. $x = (2 + p)t$

B. $x = 2 + p - t$

C. $x = 2 + \frac{p}{t}$

D. $x = \frac{(2 + p)}{t}$

2. Given the following equation:

$$P = I^2 R$$

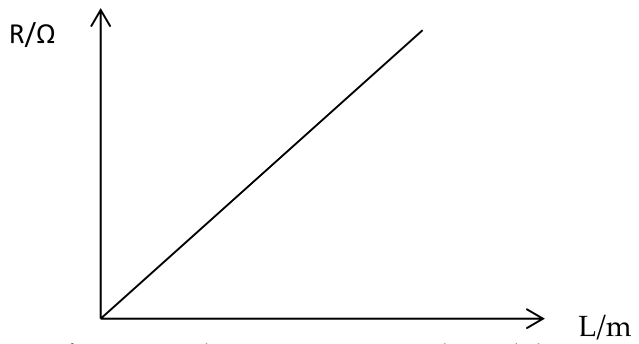
where P is power, I is current and R is resistance,
rearrange the formula so that I is the subject.

3. The equation for the resistivity of a metal ρ is usually given in the form:

$$R = \frac{\rho L}{A}$$

where R is resistance, ρ is resistivity, L is length and A is the cross-sectional area.

a) Write the equation in a more convenient form for finding the resistivity ρ of a material.



The resistive properties of a material were investigated in a laboratory setting.

Physicists used the graph to determine that the gradient (m) of the line is $m = \frac{\rho}{A}$

b) How can the equation for the gradient be rearranged for solving for ρ?

4. The equation for determining the intensity of radiation from a point source is:

$$I = \frac{P}{4\pi r^2}$$

where P is power, and r is distance from point source.

A physicist wants to determine how far away (r) the star she is studying is from Earth.
Rearrange the equation so it is in a more convenient form to calculate r.

SKILL B9: SOLVING ALGEBRAIC EQUATIONS, INCLUDING QUADRATICS

Part A: Specification Overview

Solving algebraic equations forms the basis to solving all calculations in this course. You will be required to substitute values for variables into algebraic equations and solve them.

The skill is assessed in every topic of the course specification.

Part B: Theoretical Overview

The method for solving algebraic equations is simple. It will require you to build upon your knowledge of changing the subject of the formulas.

An algebraic equation simply refers to any equation where one or more variables in the equation are unknown.

To solve the algebraic equation:

1. Change the subject of the equation to the variable you are trying to find.

   This will require you to use inverse operations.

   Note: If the variable you want to find is already the subject then you can skip step 1.

2. Secondly, insert in the values for variables you have and work through the calculation to find your unknown.

Part C: Worked Example

The mass of the Earth is $M_E = 5.98\times10^{24}$ kg and the mass of a geostationary satellite is $M_s = 250$ kg.

The orbital radius of a geostationary satellite is roughly 42,157 km and the gravitational constant G is $6.67\times10^{-11}\,\text{m}^3\text{kg}^{-1}\text{s}^{-2}$.

The equation for gravitational potential energy between two objects is:

$$U = -G\frac{M_1 M_2}{r},$$

where M_1 is the mass of object 1, M_2 is the mass of object 2, G is the gravitational constant and r is the distance between the objects.

Calculate the potential energy (U) possessed by the geostationary satellite.

Solution:

1. We do not need to rearrange the formula as U is already the subject.
2. Insert in the numerical values for the variables into the equation and work through.

$$U = -G\frac{M_E M_S}{r}$$

$$U = -(6.67\times10^{-11})\times\left(\frac{\left(5.98\times10^{24}\right)\times(250)}{(42157\times10^3)}\right)$$

$$U = -(6.67\times10^{-11})\times(3.546267524\times10^{19})$$

$$U = -2.36\times10^{9}\text{ J}$$

Part D: Practice Questions

1. The equation for potential difference is $V = IR$, where I is current and R is the resistance.

Given that the current flowing through a 10 Ω resistor is 0.2 A, calculate the potential difference across the resistor.

2. An equation for current flowing in a conductor is given by $I = Anev$, where A is the cross-sectional area of the conductor, n is the number density, e is the charge of an electron and v is the velocity of the electron.

An electrician detects 1.20 A of current is produced in a copper wire with cross-sectional area $2.34 \times 10^{-7}\ \text{m}^2$. The number density of copper is $8.50 \times 10^{28}\ \text{m}^{-3}$.

Therefore, calculate the velocity of electrons through the copper wire.

3. Newton's second law is $F = m\left(\frac{v-u}{t}\right)$, where F is the net force acting on the object, m is the mass of an object, v is its final velocity, u is its initial velocity and t is the time of the journey.

A $7.1 \times 10^{7}\ \text{kg}$ train leaves the platform at a velocity of $0.44\ \text{ms}^{-1}$. There is a net force of $1.5 \times 10^{6}\ \text{N}$ that is applied for 360 seconds.

Calculate the velocity of the train after 360 seconds.

4. The centripetal force is the force that causes an object to travel in a circular path. When a car rounds a corner the centripetal force is supplied by the frictional force between the tyres and the road.

The equation for centripetal force is $F = \frac{mv^2}{r}$, where m is the mass of the object, v is its speed and r is the radius of its circular path.

The centripetal force is 50 N, the mass of the car is 670 kg and the radial distance of its path is 13.6 m.

Determine the speed at which the car would have been travelling as it rounded the corner.

SKILL B12: ANGLES

Part A: Specification Overview

The exam board will expect you to be able to use angles in 2D and 3D structures to interpret physical problems.

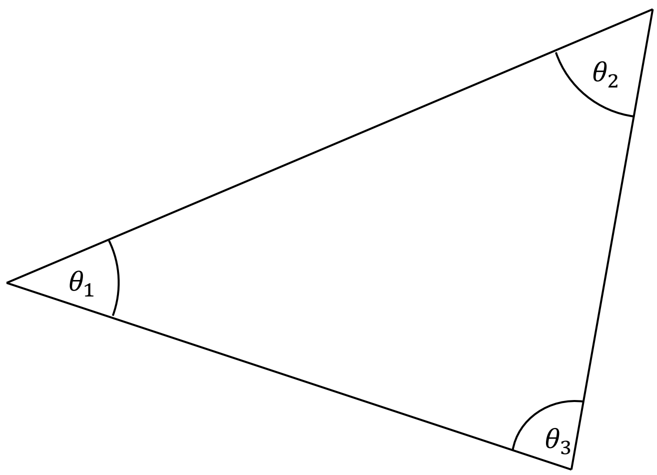
You will be required to make use of this skill throughout the course but the skill will be predominantly tested when working with force diagrams and vector resolution questions.

Part B: Theoretical Overview

To interpret and understand physical problems and applications, you will have to call upon your basic knowledge of angle rules within circles and triangles.

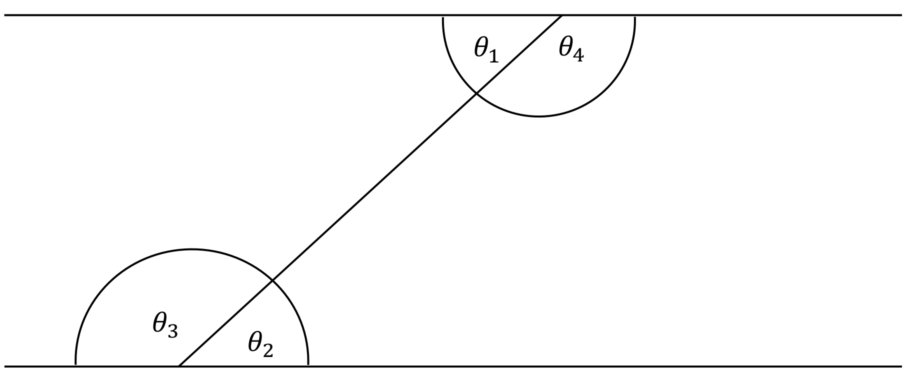
Knowledge of the following angle rules is essential when analysing physical problems in this course:

- The angles inside a triangle



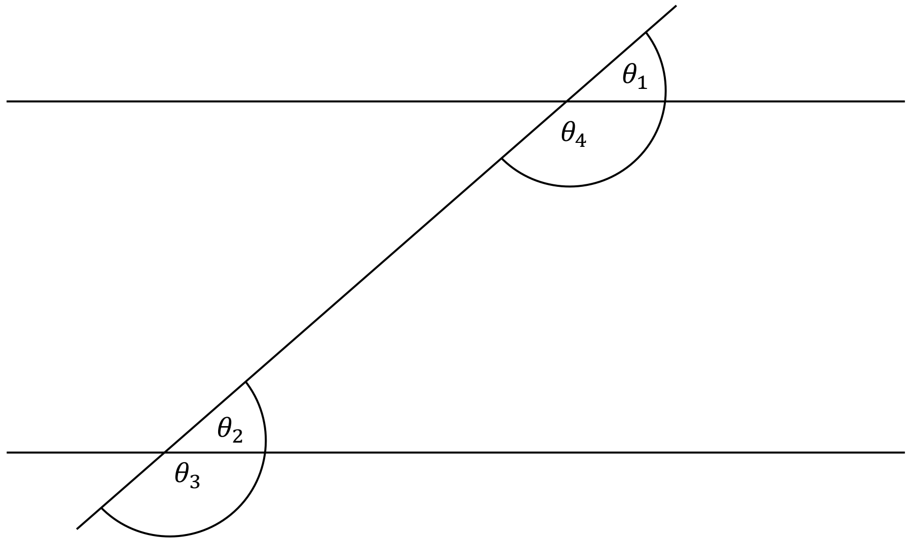
$$\theta_1 + \theta_2 + \theta_3 = 180°$$

- Angles in relation to parallel lines
  - the alternate angles are equal



$$\theta_1 = \theta_2$$
$$\theta_3 = \theta_4$$

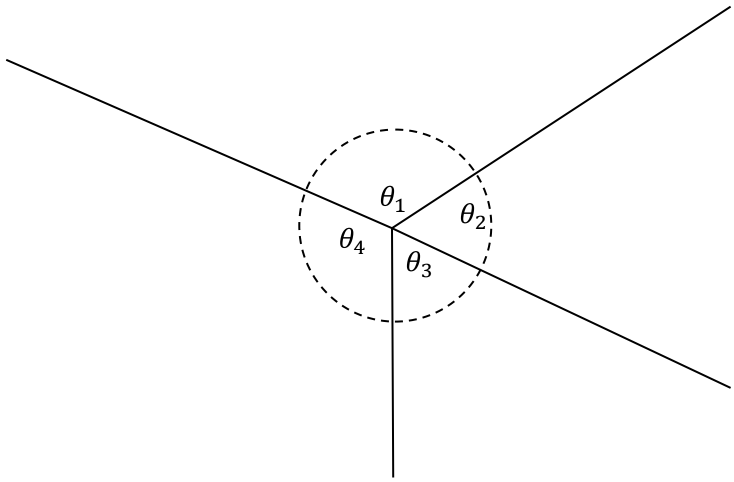
- the corresponding angles are equal



$$\theta_1 = \theta_2$$

$$\theta_3 = \theta_4$$

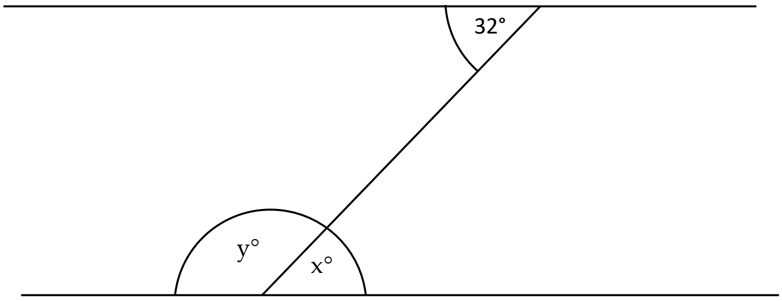
- All angles that meet at a point must add up to 360°



$$\theta_1 + \theta_2 + \theta_3 + \theta_4 = 360°$$

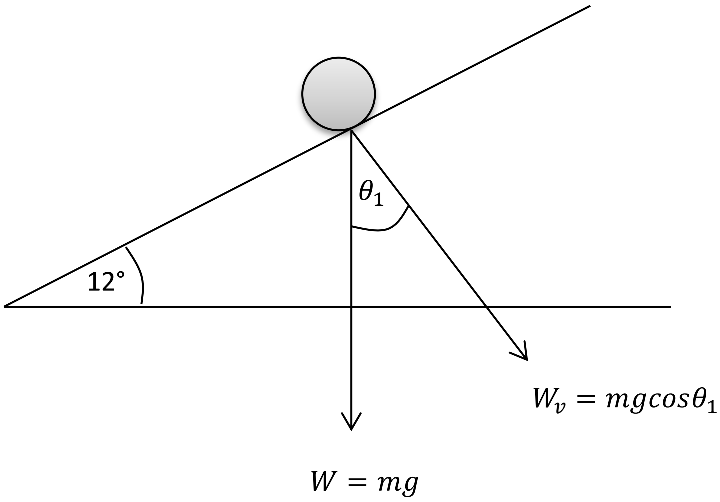
Part C: Worked Example:

1. Calculate the missing angles x and y.



2. A ball is rolling down an inclined plane as demonstrated below:

Note: Diagrams not drawn to scale.



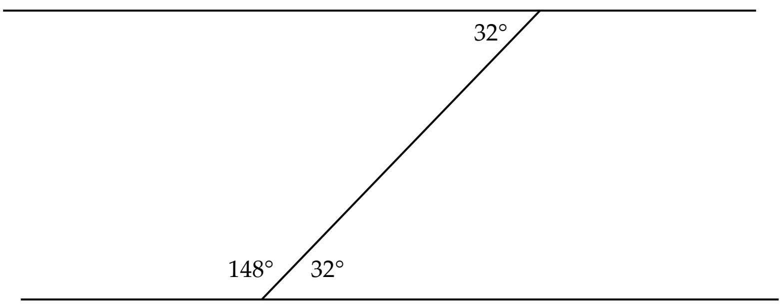
In order to calculate the vertical component of weight, the angle θ_1 needs to be evaluated.

a) Calculate the value of θ_1 using your knowledge of angles on parallel lines.

b) Write the expression for W_v in terms of θ_1 found in (a).

Solution:

1.

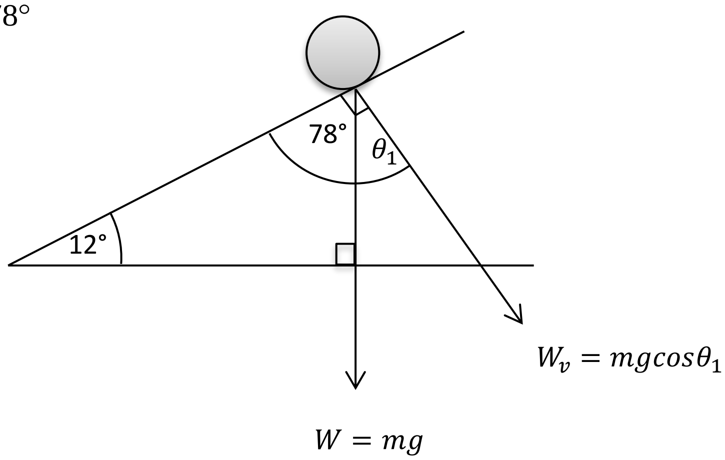


- The rule of alternate angles on parallel lines mean that $x = 32°$
- Since x and y are on a parallel line they have to add to 180°. Therefore: $y = 180 - x = 180 - 32 = 148°$

2. a) The angles of a right-angled triangle add up to 180°.

Therefore, the remaining angle of the triangle created by W and the inclined plane can be found:

$180° - (12° + 90°) = 78°$



Then, since W_v is perpendicular to the slope of the inclined plane, the angle between W_v and the slope is 90°.

Therefore, θ_1 can be found from,

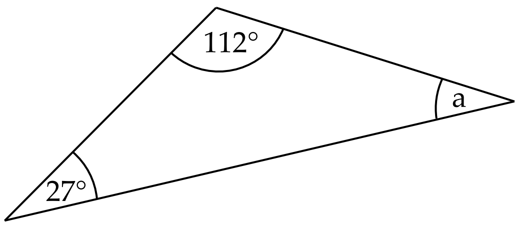
$\theta_1 = 90 - 78 = 12°$

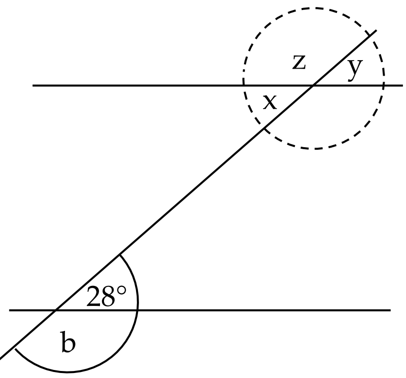
b) $W_v = mg\cos\theta_1$

$W_v = mg\cos 12°$

Part D: Practice Questions

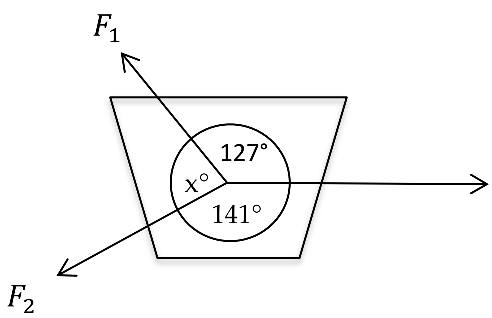
1. Find the missing angles.





Note: Diagrams not drawn to scale.

2. The following force diagram represents the forces acting on a boat.



Calculate the angle between F_1 and F_2.

Skill B13: Converting between radians and degrees

Part A: Specification Overview

The specification states that as a physics student you should be comfortable with the relationship between degrees and radians and be able convert from one form to the other.

You will be expected to be able to demonstrate this skill in vector resolutions and force diagrams. The skill will also be tested in electromagnetic waves and refraction topics.

Part B: Theoretical Overview

Degrees and radians are simply two different units used to describe an angle. You might feel more comfortable with degrees as the unit of angles in a circle, but radian is simply just a different unit for the same value.

It is similar to measuring the length of a variable; we can measure in miles, kilometres or feet.

Let's say you have an angle in degrees and you want to convert it into radians; you would use the following equation to do so:

$$radians = degrees \times \frac{\pi}{180}$$

In a similar fashion, if you had your angle in radians and wanted to convert it back into degrees you would use the following equation:

$$degrees = radians \times \frac{180}{\pi}$$

Part C: Worked Example

A light ray hits the window of a car and refracts as it travels from air to glass.

The angle of refraction is measured to be 67°.

a) Calculate the angle of refraction in radians.

Another light ray hits the car window, and this time the angle of incidence of the light ray at the boundary is measured to be 0.64 radians.

b) Calculate the angle of incidence in degrees.

Solution:

a) $angle\ in\ radians = 67 \times \frac{\pi}{180}$

1.17 radians

b) $angle\ in\ degrees\ =\ 0.64 \times \frac{180}{\pi}$

$= 36.67°$

$= 37°$

Part D: Practice Questions

1. Which of the following is equal to 32°?

A. 1833 radians
B. 0.56 radians
C. 5760 radians
D. 0.17 radians

2. Convert the following angles into radians:

a) 45°
b) 126°
c) 542°

3. Convert the following angles into degrees:

a) 5.6 radians
b) 1.22 radians
c) 0.23 radians

4. When light travels across the boundary of two materials it will change direction.

The critical angle, given by $\sin C = \frac{1}{n}$, is the incident angle of a light ray that causes the light ray to change direction and reflects backwards.

The refractive index (n) is 1.52.

Calculate the critical angle.

SKILL B14: VISUALISING AND REPRESENTING STRUCTURES AND PROBLEMS AND CALCULATING AREAS AND VOLUMES

Part A: Specification Overview

The exam board states that a requirement for this course is an ability to calculate the areas of triangles, circumferences and areas of circles, and the surface areas of rectangular blocks, cylinders, and spheres. Additionally, you will be expected to know how to calculate the volume of rectangular blocks, cylinders and spheres.

This skill will be crucial when working on physical problems. The skill will be the first step towards determining physical properties of the problem. You will see this skill tested in motion, density and pressure, and resistivity topics.

Part B: Theoretical Overview

Area

This course will require you to calculate the following areas using the following equation.

Circle:

- The circumference of a circle is given by:

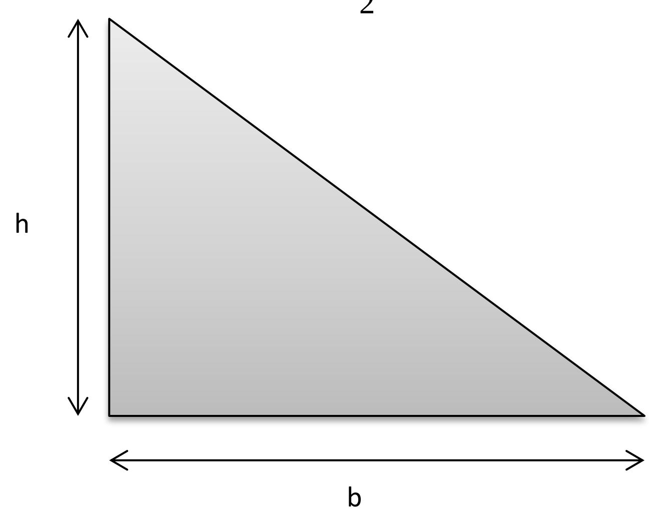
$$C = \pi \times d$$
or
$$C = \pi \times (2 \times r)$$
where r is the radius and d is diameter

- The area of a circle is given by:

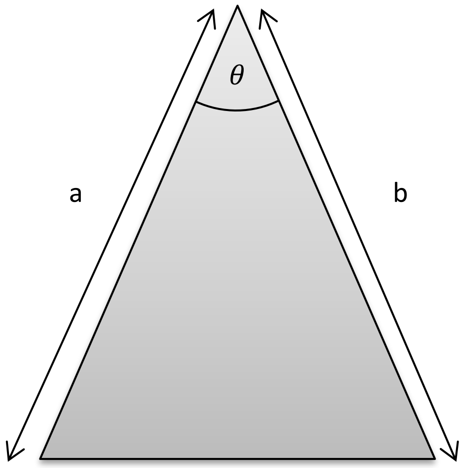
$$A = \pi r^2$$
or
$$A = \pi \left(\frac{d}{2}\right)^2$$

Triangle:

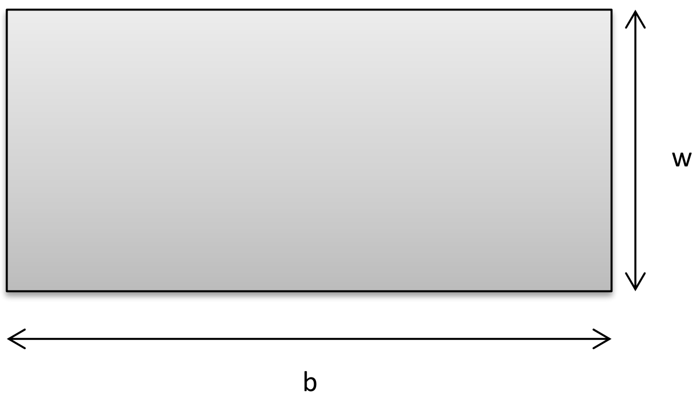
- The area of a right–angled triangle is given by: $A = \frac{1}{2} \times b \times h$



The area of a non-right-angled triangle is given by: $A = \frac{1}{2}ab\sin\theta$



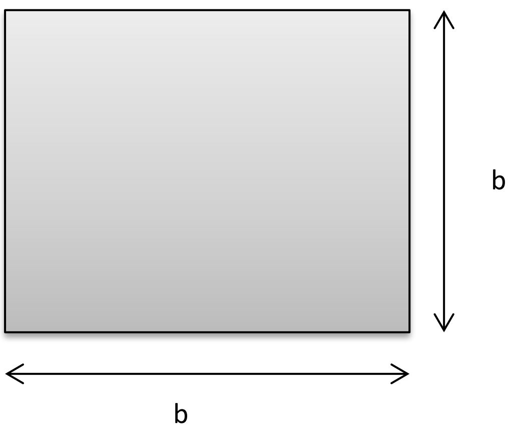
Square/Rectangle:



The area of a rectangle is given by:

$$A = b \times w$$

The special case for this is the case of the square when $b = w$



The area is then given by:

$$A = b \times b$$
$$A = b^2$$

Surface Area:

Volume

The general equation for the volume of any shape is given by:

$$V = A \times h$$

where A is the surface area of one of the sides of the shape and h is the height.

Note: The equation for surface area depends on the shape; for a cylinder, for example, the surface area will be the equation for the area of a circle, whereas the surface area for a rectangular block will be the equation for the area of a rectangle.

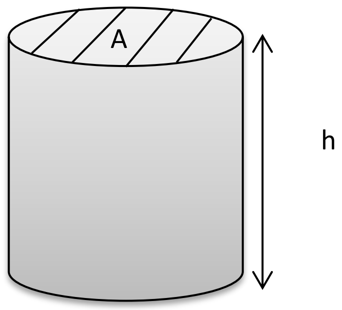
The equation can be applied to any prism.

Cylinder

If we apply the general equation to the cylinder we obtain:

$V = A \times h$

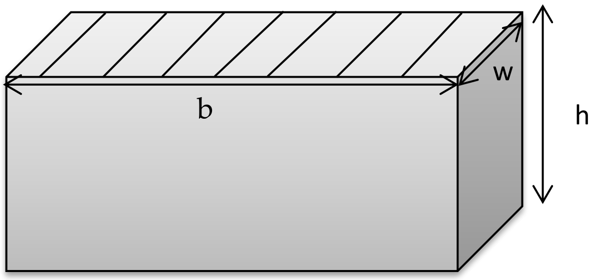
$V = (\pi r^2) \times h$



Rectangular block

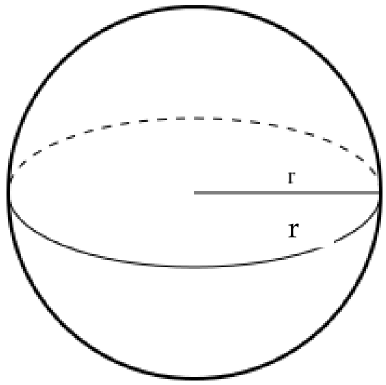
$V = A \times h$

$V = (b \times w) \times h$



Sphere

$$V = \frac{4}{3}\pi r^3$$



Part C: Worked Example

1. **Calculate the cross-sectional area of a cylinder with radius $r = 1.6\text{ m}$.**
2. **An energy company is wanting to determine the resistivity of the wires used in one of its machines.**
   The resistivity of a wire can be determined using the following equation:

$$\rho = \frac{RA}{L}$$

where ρ is the resistivity of the material, R is the resistance of the material, A is the cross-sectional area and L is the length of the material.
The wires used are cylindrical in shape, with a radius of 2.0 mm and length 10 cm. If the resistance of the wires is known to be 10 Ω, calculate the resistivity of the wire.

Solution:

1. Cross-sectional area = area of a circle:

$A = \pi r^2$

$A = \pi \times (1.6)^2$

$A = 8.0\text{ m}^2$

2. $\rho = \frac{RA}{L}$

$\rho = \frac{10 \times A}{(10\times10^{-2})}$

Therefore, before the equation can be used to determine ρ, the cross-sectional area A must be evaluated.
The cross-sectional area of a cylindrical object is a circle. Therefore:

$A = \pi r^2$

$A = \pi \times (2\times10^{-3})^2$

$A = 1.3\times10^{-5}\text{ m}^2$

Therefore, the resistivity of the wire is:

$\rho = \frac{10\times\left(1.3\times10^{-5)}\right)}{(10\times10^{-2})}$

$\rho = 1.3\times10^{-3}\ \Omega\text{m}^{-1}$

Part D: Practice Questions

1. A cylindrical barrel is being used in an experiment that investigates the buoyancy of an object. To carry out the experiment, the volume of the barrel needs to be known. It has a diameter of 0.36 m and a length of 0.63 m.

a) Calculate the volume of the barrel.

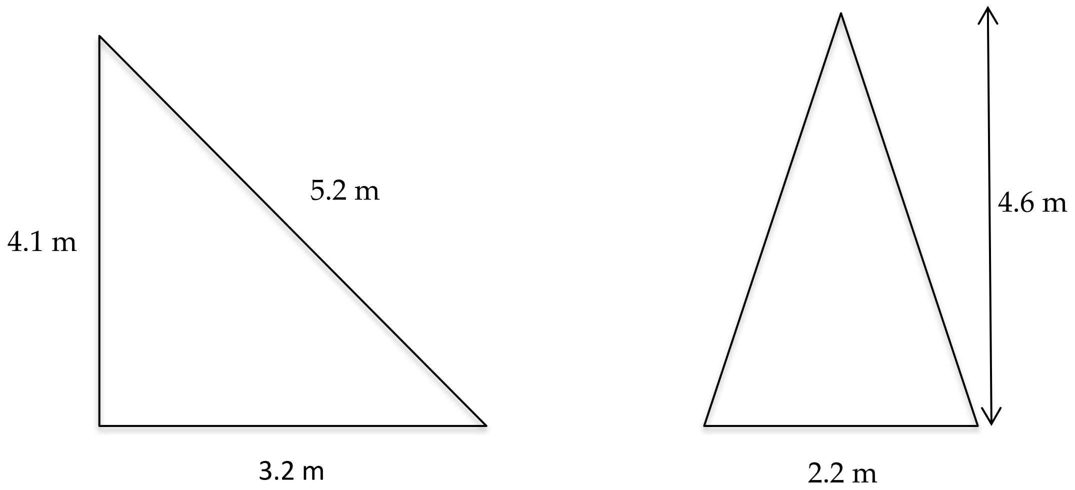
b) Calculate the circumference of the barrel.

The experiment is repeated with a rectangular trunk with dimensions 0.20 m × 0.30 m × 0.60 m.

c) Calculate the area of one of its faces.

d) Calculate the volume of the trunk.

2. Determine the area of the following two triangles:



3. A rectangular box, used for recording animal sounds in the sea, is floating on the top of the water.

The rectangular box has the dimensions 0.300 × 0.500 × 0.600.

The equation for determining the buoyancy (B) acting on the box is given by:

$$B = \rho V g$$

where V is the volume of the box, $g = 9.81\ \mathrm{ms}^{-2}$ is the acceleration due to gravity and $\rho = 4.56\ \mathrm{kgm}^{-3}$ is the density of the box.

Using the equation, calculate the buoyancy acting on the box.

SKILL B15: MATHEMATICAL SYMBOLS

Part A: Specification Overview

The exam board will expect you to understand and use the symbols: $=, <, \ll, \gg, >, \propto, \approx, \Delta$. You will be tested on your ability to recognise the significance of these symbols in mathematical expressions and work with the expressions to find numerical solutions.

This skill will be tested in every topic in this course; therefore, a grasp of this skill is essential in the course.

Part B: Theoretical Overview

You will be expected to know what the following symbols mean and additionally what they mean in the context of mathematical expressions.

Symbol	Meaning	Context	Contextual Meaning
=	Equal to	X = 3	'x is equal to 3'
<	Less than	5 < 7	'5 is less than 7'
$\ll$	Much less than	1 $\ll$ 10,000	'1 is much less than 10,000'
$\gg$	Much greater than	785 $\gg$ 0.02	'785 is much greater than 0.02'
>	Greater than	Velocity 1 > Velocity 2	'Velocity 1 is greater than Velocity 2'
$\propto$	Proportional	Force $\propto$ acceleration	'Force is proportional to acceleration'
$\approx$	Approximately equal	1.234 $\approx$ 1.233	'1.234 is approximately equal to 1.233'
Δ	Change in	Δ T	'Change in T'

Part C: Worked Example

It can be said that during a collision or impact the net force exerted is given by the expression $F \propto \frac{\Delta p}{\Delta t}$, where p is momentum and t is the time of the impact of collision.

Using your knowledge of mathematical symbols, indicate what effect a larger net force will have during impact.

Solution:

The equation $F \propto \frac{\Delta p}{\Delta t}$ reads 'Net force is proportional to the change in momentum over the change in time'. Therefore, it can be said that if there is a greater net force during impact than there will be a proportionally greater change in momentum over change in time.

Part D: Practice Questions

1. Which of the following statements are true, and which are false?

A. $a \ll D$; 'D is much greater than a'

B. $F \propto m$; 'F is approximately equal to m'

C. $x > 7$; '7 is greater than x'

D. $a = \Delta v$; 'a is approximately equal to the change in v'

2. Write the following statements in terms of their mathematical symbols:

a) Pressure is proportional to force

b) Current is much less than potential difference

c) B is greater than C

3. Researchers at CERN are carrying out experiments with subatomic particles and therefore have to use quantum mechanics to explain their properties.

A key concept underpinning quantum mechanics is that, for a photon, $E \propto f$, where E is the energy of a photon and f is the frequency of the photon.

Explain what is meant by this statement.

From your explanation, deduce what you think might happen to f if E was increased.