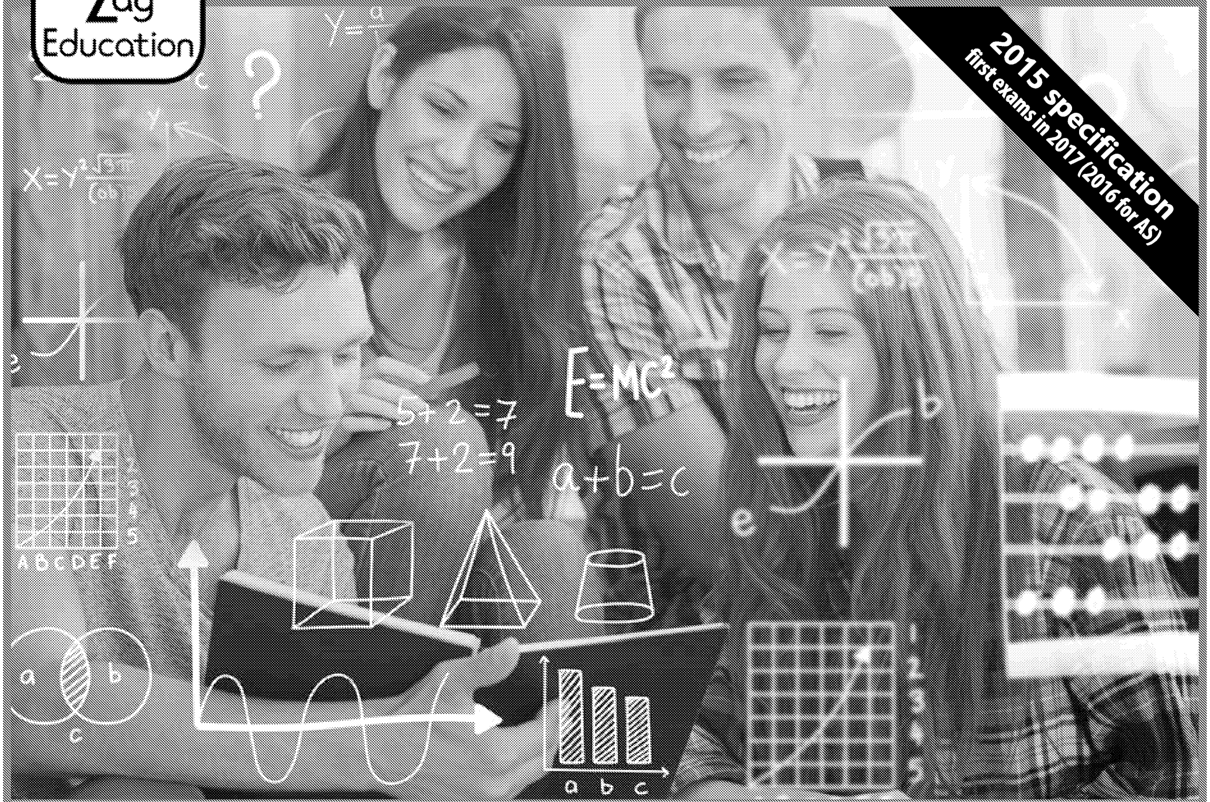
Physics

AS and A Level



Mastering Maths for AS and A Level Physics

Basic Maths Skills

Second Edition, May 2024

zigzageducation.co.uk

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Contents

Teacher's Introduction

The following exam boards have a published list of the mandatory mathematical skills requirement for each of their Physics courses:

- AS and A Level AQA Physics (7407 and 7408)
- AS and A Level OCR Physics A (H156 and H556)
- AS and A Level OCR Physics B (H157 and H557)
- AS and A Level Edexcel Physics (8PH0 and 9PH0)
- AS and A Level WJEC Eduqas Physics (B420QS and A420QS)
- AS and A Level WJEC Physics (2420 series and 1420 series)

The required mathematical skills are driven by the Department for Education. The assessment marks of quantitative skills in both AS and A Level papers will comprise a minimum of 40% of the required mathematical skills for Physics (Level 2 or above).

Physics students sometimes find the mathematical skills required for success a challenge, especially when expected to apply them to the context of physics. This Mastering Maths skills resource has been designed with the intention of providing them with the opportunity to review the mathematical skills familiar to them from GCSE higher-tier courses, and practise them in the context of the specific topics in the Physics course that require an understanding of them. This pack outlines the basic maths skills required (see mapping document in Chapter 1) and allows students to become comfortable and competent with the basics before teaching the Physics course.

The resource is split into **three chapters**:

Chapter One: Mapping Table
This section includes a table mapping each basic maths skill outlined in the exam boards' published list to each specification point where the skill is found.

Chapter Two: Diagnostic Test
This section includes two diagnostic tests, of the same format, that cover all the basic mathematical skills outlined by the exam board. Both tests have the same format and therefore can act as an effective comparison tool, and each has questions increasing in difficulty and therefore accessible to varying abilities.

It is recommended that the students are given the first diagnostic test to complete before the AS Physics course has been taught, with the purpose of highlighting any gaps in their knowledge and assessing their competency.

The second test is slightly harder and can be given at any point during the course. The second test works on two levels; it is a useful positive reinforcement tool for the students, where they can see how their knowledge has improved, and can also assess where the areas of difficulty and gaps in the knowledge still remain.

Both tests indicate the mathematical skills tested in each question, and therefore specific skills with which the students are still struggling can be particularly identified.

Chapter Three: Basic Maths Skills
This section covers all the basic mathematical skills mentioned in the exam boards' published requirements list, which students should be familiar with from their GCSE Maths courses.

Students have the opportunity to complete both short and structured questions that will help develop the necessary numerical skills and consolidate understanding. These questions should build students' confidence in having the required ability to demonstrate their full potential in AS and A Level Physics, in both class and examination conditions.

Each basic maths skill is structured as follows:

- **Part A: Specification Overview** – this provides an overview of the skill and explains to the student what the exam board requires them to demonstrate in the exam with the skill.
- **Part B: Theoretical Overview** – a brief summary recapping the skill and demonstrating how the student is to apply the skill to the context of their physics topics.
- **Part C: Example** – detailed numerical example with worked solution of the skill in context of a topic where the skill will be found.
- **Part D: Practice Activity** – each skill is concluded with practice questions that increase in difficulty. All the physics knowledge needed to complete the question will be provided and the question focuses on testing the student's understanding of the maths skill itself.

This is followed by:

- The **Mark Scheme for Diagnostic Test**, which provides a mark scheme with worked solutions for the diagnostic test.
- Suggested **Answers to Part D: Practice Questions**, which provides worked solutions for each set of practice questions.

October 2016

Second edition, May 2024
A number of improvements have been made from the first edition.

CHAPTER 1: MAPPING MATHS SKILLS TO SPECIFICATION POINTS

! Skills in **bold font** are only tested in the full A Level course

AQA	OCR (A/B)	Edexcel	WJEC/ Eduqas		Basic skills	Further skills
Arithmetic and numerical computation						
MS 0.1	M 0.1	C.0.1	No reference numbers	Recognise and make use of appropriate units in calculations	B1	
MS 0.2	M 0.2	C. 0.2		Recognise and use expressions in decimal and standard form	B2	
MS 0.3	M 0.3	C.0.3		Use ratios, fractions and percentages	Tested throughout skills	
MS 0.4	M 0.4	C 0.4		Estimate results	B3	
MS 0.5	M 0.5	C.0.5		Use calculators to find and use power functions, **exponential and logarithmic functions**	B7	F10, F11
MS 0.6	M 0.6	C.0.6		Use calculator to handle sin *x*, cos *x*, tan *x* when *x* is expressed in degrees or radians	B6	
Handling data						
MS 1.1	M 1.1	C.1.1	No reference numbers	Use an appropriate number of significant figures	B4	
MS 1.2	M 1.2	C.1.2		Find arithmetic means	B5	
MS 1.3	M 1.3	C.1.3		Understand simple probability	B16	
MS 1.4	M 1.4	C.1.4		Make order of magnitude calculations	B1	
MS 1.5	M 1.5	C.1.5		Identify uncertainties in measurements and use simple techniques to determine uncertainty when data are combined by addition, subtraction, multiplication, division and raising to powers	B10, B11	
Algebra						
MS 2.1	M 2.1	C.2.1	No reference numbers	Understand and use the symbols: $=, <, \ll, \gg, >, \propto, \approx, \Delta$	B15	
MS 2.2	M 2.2	C.2.2		Change the subject of an equation, including non-linear equations	B8	
MS 2.3	M 2.3	C.2.3		Substitute numerical values into algebraic equations using appropriate units for physical quantities	B9	
MS 2.4	M 2.4	C 2.4		Solve algebraic equations, including quadratic equations	B9	
MS 2.5	M 2.5	C.2.5		**Use logarithms in relation to quantities that range over several orders of magnitude**		F11
Graphs						
MS 3.1	M 3.1	C.3.1	No reference numbers	Translate information between graphical, numerical and algebraic forms		F5
MS 3.2	M 3.2	C. 3.2		Plot two variables from experimental or other data		F4
MS 3.3	M 3.3	C.3.3		Understand that $y = mx + c$ represents a linear relationship	B8	F5
MS 3.4	M 3.4	C.3.4		Determine the slope and intercept of a linear graph		F5
MS 3.5	M 3.5	C.3.5		Calculate rate of change from a graph showing a linear relationship		F6
MS 3.6	M 3.6	C.3.6		Draw and use slope of tangent to curve as a measure of rate of change		F6
MS 3.7	M 3.7	C.3.7		Distinguish between instantaneous rate of change and average rate of change		F6
MS 3.8	M 3.8	C.3.8		Understand the possible physical significance of the area between a curve and the x-axis and be able to calculate it or estimate it by graphical methods as appropriate		F8
MS 3.9	M 3.9	C.3.9		Apply concepts underlying calculus (but without requiring the explicit use of derivatives or integrals) by solving equations involving rates of change, e.g. $\frac{\Delta x}{\Delta t} = -\lambda x$ using graphical method or spreadsheet modelling		F7
MS 3.10	M 3.10	C.3.10		**Interpret logarithmic plots**		F12
MS 3.11	M 3.11	C.3.11		**Use logarithmic plots to test exponential and power law variations**		F12
MS 3.12	M 3.12	C.3.12		Sketch relationships which are modelled by $y = \frac{k}{x}$, $y = kx^2$, $y = \frac{k}{x^2}$, $y = kx$, $y = \sin x$, $y = \cos x$, $\mathbf{y = e^{\pm x}}$ and $\mathbf{y = \sin^2 x, y = \cos^2 x}$ **as applied to physical relationships**		F9

Geometry and trigonometry						
MS 4.1	M 4.1	C.4.1	No reference numbers	Use angles in regular 2D and 3D structures	B12	
MS 4.2	M 4.2	C.4.2		Visualise and represent 2D and 3D forms including two-dimensional representations of 3D objects	B14	
MS 4.3	M 4.3	C.4.3		Calculate areas of triangles, circumferences and areas of circles, and surface areas and volumes of rectangular blocks, cylinders and spheres	B14	
MS 4.4	M 4.4	C. 4.4		Use Pythagoras's theorem, and the angle sum of triangle		F1
MS 4.5	M 4.5	C. 4.5		Use sin, cos, and tan in physics problems		F2
MS 4.6	M 4.6	C.4.6		Use small angle approximations including $\sin\theta \approx \theta, \tan\theta \approx \theta, \cos\theta \approx 1$ for small θ where appropriate		F3
MS 4.7	M 4.7	C.4.7		Understand the relationship between degrees and radians and translate from one to the other	B13	

Maths skill in this resource	Maths skill in specification
Skill B1	Skills 0.1/1.4
Skill B2	Skill 0.2
Skill B3	Skill 0.4
Skill B4	Skill 1.1
Skill B5	Skill 1.2
Skill B6	Skill 0.6
Skill B7	Skill 0.5
Skill B8	Skill 2.2
Skill B9	Skills 2.3/2.4
Skill B10	Skill 1.5
Skill B11	Skill 1.5
Skill B12	Skill 4.1
Skill B13	Skill 4.7
Skill B14	Skills 4.2/4.3
Skill B15	Skill 2.1
Skill B16	Skill 1.3

Diagnostic Test 1

1. Write the following number in standard form: 4,580,000

2. Write the following number as a whole number: 9.37×10^4

3. Convert 151° into radians

4. Convert 0.15 radians into degrees

5. State the equation for determining the area of the following shapes:
   a) Circle
   b) Right-angled triangle

6. Write the following numbers to 4 significant figures:
   a) 402,369.2
   b) 0.2048539

7. State the SI units of the following physical quantities:
   a) Mass
   b) Length
   c) Current
   d) Power

8. Evaluate x in the following equations. Assume that each equation is
   a) $\sin x = 0.630$
   b) $\cos 32 = x$
   c) $\tan 156 = x$

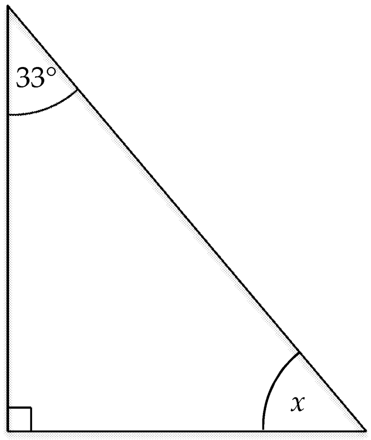
9. The temperature of the sun is 5778 K.
   a) Write the temperature of the sun in standard form
   b) Write the value for the temperature of the sun to 3 significant fig

10. Explain in words the following mathematical statements:
    a) $A \propto \Delta B$
    b) $C \leq D < E$
    c) $F >> G \geq H$

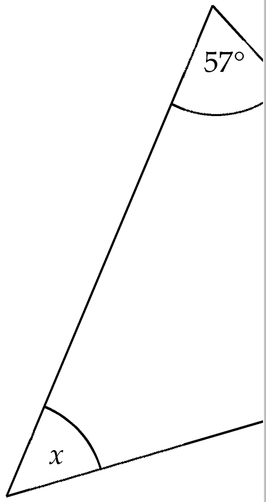
11. Find the missing angle x in the following triangles.

Note: the following diagrams are not to scale.

a)

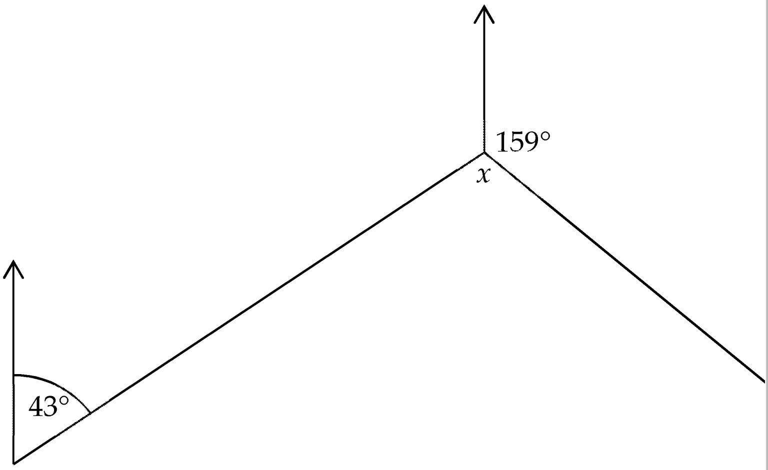


b)



12. A boat is travelling on an initial bearing of 43° and then changes cour

The boat bearing changes to 159°.



Determine the angle x.

13. Given that $P = I^2R$ and $I = 3.00$ A and $R = 14.0\ \Omega$, find P.

14. Given the following results for frequency f and wavelength λ

$$f = 2.3 \pm 0.1\ \text{Hz};\ \lambda = 0.02 \pm 0.01\ \text{m}$$

a) State the absolute uncertainty of f
b) State the absolute uncertainty of λ
c) Determine the velocity of the wave with the equation $v = f\lambda$, incl the uncertainty

15. A Physics student measured value for density of a block to be $56.9 \pm$

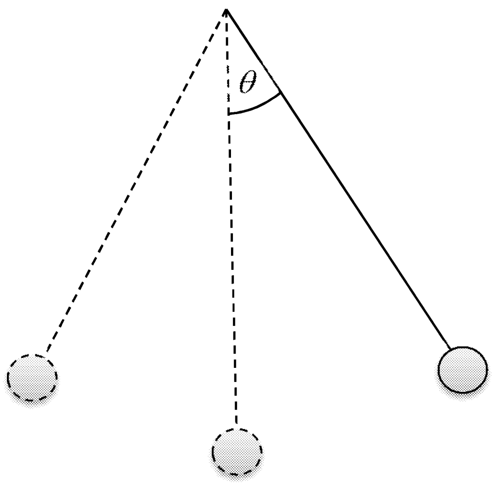
Determine the percentage uncertainty in the value for density.

16. A lab technician measures the length of an electrical wire to be 0.21 m

The lab technician measures the length of the wire again a few hours

Determine the percentage change in the measured value for length of

17. When we discuss a pendulum swinging, we don't discuss the distanc metres m but through an angle θ.



The equation for determining the angle the pendulum has swung thr

$$\theta = A\sin(xt)$$

where A = 3.40 m, x = 1.60 rads^{-1} and t = 1.70 s.

Calculate the angle the pendulum has swung through using the equa in degrees.

18. In physics, we use the equations of motion to determine how an objec

The equation for determining the final velocity of an object is:

$$v^2 = u^2 + 2as$$

where v is the final velocity of an object, u is the initial velocity, a is and s is the displacement travelled by the object.

If a cyclist is initially cycling at $5.8\ \text{ms}^{-1}$, and begins to accelerate at 0

d) What will the final velocity (v) of the cyclist be after 10 m?

19. An astronomer is attempting to determine the velocity of our galaxy.

She obtains the following measurements:

Velocity (kmh^{-1})			
v_1	v_2	v_3	v_4
828×10^3	827×10^3	824×10^3	827×10^3

Calculate the mean of the astronomer's results.

20. Using your knowledge of probability, explain how the process of thr
process of radioactive decay.

21. A charged particle gains energy as it travels between two electrically
The equation for the kinetic energy gained by an initially stationary p

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

a) State the SI base unit for energy.

A charged particle of mass 1.67×10^{-27} kg reaches a maximum velocity
two charged plates.

b) Use the energy equation to determine the energy gained by the pa
plates. Give your answer in standard form.

c) Write your answer to (b) using a prefix.

22. A spring with a spring constant $k = 3.0 \times 10^4$ Nm^{-1} is extended by 20 c
A force must have been acting on the spring in order to extend it. The

$$F = kx$$

where x is the extension length and k is the spring constant.

a) Calculate the force exerted on the spring.
b) Convert your answer to (a) into kN.

23. The equation for the gravitational potential energy of an object of ma
centre of a massive body with mass *M* is given by:

$$E_{\text{grav}} = -\frac{GMm}{r}$$

a) In a system where the massive body is the Sun and the object orb
gravitational potential energy of the system.

Note:
G is a gravitational constant given by 6.67×10^{-11} Nm^2 kg^{-2}
The mass of the Sun is 1.99×10^{30} kg
The mass of Earth is 6.00×10^{24} kg
The distance between Earth and the Sun is 1.50×10^{11} m

b) What is your answer to (a) in kJ?
c) Write your answer to (a) to 1 significant figure.

Similarly, the force of attraction (gravitational force) between two boc
following formula:

$$F = -\frac{Gm_1m_2}{r^2}$$

d) Using this formula, estimate the force of attraction between an ac
distance of one metre, in the absence of any other objects. Apply
wherever necessary. **(Skills**

Diagnostic Test 2

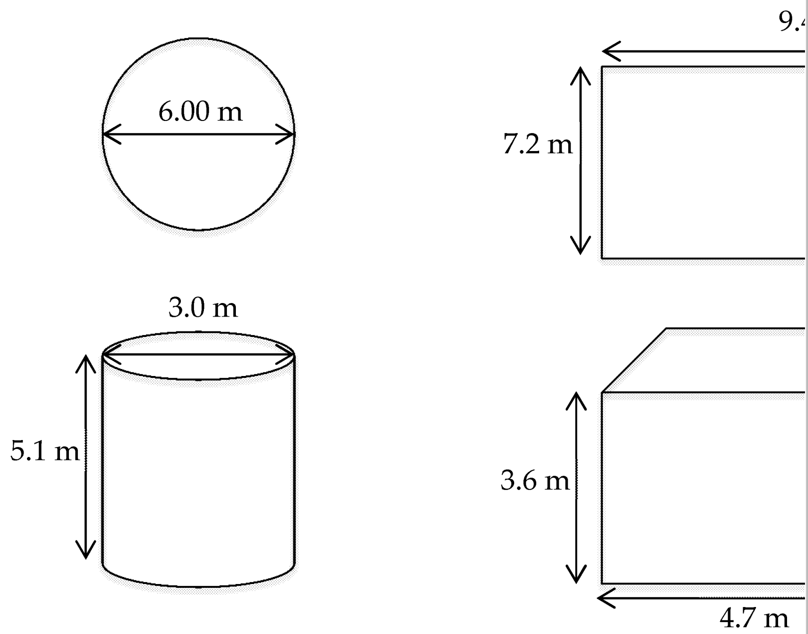
1. Write the following number in standard form: 236,900,000

2. Write the following number as a whole number: 6.31×10^{-3}

3. Convert 68° into radians

4. Convert 1.28 radians into degrees

5. Determine the area/volume of the following shapes:



6. Write the following numbers to 6 significant figures:

   a) 53021.59
   b) 0.0365821
   c) 0.00000023 (provide an answer with the fewest number of decima

7. State the SI units of the following physical quantities:

   a) Amount of a substance
   b) Resistance
   c) Volume
   d) Time

8. Evaluate x in the following equations. Assume that each equation is

   a) $\cos x = 0.69$
   b) $\sin 89 = x$
   c) $\tan x = 0.47$

9. The universe is 13,820,000,000 years old.

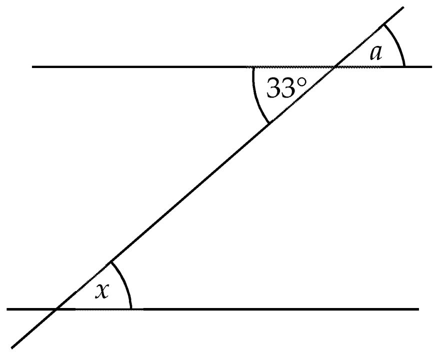
   a) Write the age of the universe in standard form.
   b) Write the value for the age of the universe to 3 significant figures

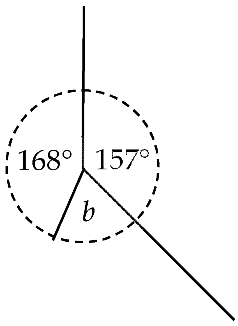
10. Explain in words the following mathematical statements:

    a) $A \ll B \ll \Delta C$
    b) $C \leq \dfrac{\Delta D}{\Delta E}$
    c) $F \propto x$ if $x \geq 3$

11. Find the missing angles:

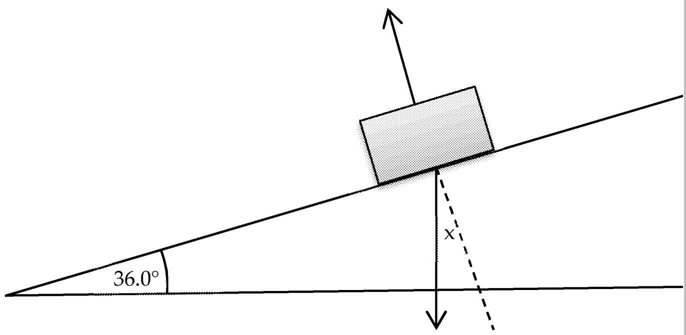
Note: the following diagrams are not to scale.





12. A rally car company draws a force diagram of the forces acting on the assess its movement.

    The angle x is missing from the force diagram.



   a) Using your knowledge of angles, evaluate the missing angle x.

      If the rally car parks on a slope without its handbrake on it will s gravity. The acceleration at which is slides due to gravity is give

$$a = g \sin x$$

   b) Using your answer to (a) determine the acceleration down the slo

Note: You can assume that the friction between the tyres and th

13. Given that $s = ut + \frac{1}{2}at^2$ and $u = 2.50\ \text{ms}^{-1}$, $t = 150\ \text{s}$ and $a = 0.200$ m

14. Given the following results for frequency *f* and wavelength λ:

$$f = 150 \pm 1\ \text{Hz};\ \lambda = 3.3 \pm 0.1\ \text{m}$$

a) State the absolute uncertainty of *f*
b) State the absolute uncertainty of λ
c) Determine the velocity of the wave with the equation $v = f\lambda$

15. A Physics student obtains the following measurement for resistance:

Determine the percentage uncertainty of the value for resistance.

16. A research group is completing experimental tests into the correlatior

The group exerts a constant force on a table and measures the resultir $30 \pm 2\text{Pa}$.

The group increases the force exerted and the measurement for pressı

Determine the percentage increase from the first reading in the measu

17. Charged particles accelerate between electrically charged plates.

The potential difference V between the plates is determined using the velocity of an initially stationary charged particle:

$$V = \frac{mv^2}{2e}$$

An electron ($m_e = 9.11 \times 10^{-31}$ kg; $e = 1.6 \times 10^{-19}$ C) reaches a final velo two charged plates.

Determine the potential difference between the plates.

18. An energy company completes operational testing into the efficiency

It repeated the test a number of times and achieved the following resu

E_1	E_2	E_3	E_4	
98.6%	98.9%	98.7%	98.9%	

Calculate the mean of the energy company's results for energy efficie

19. The kinetic energy of a moving object can be calculated using the follo

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

Using this formula, estimate the kinetic energy of a car driven on a m Apply sensible estimations where necessary.

20. Ohm's law states that, for any electrical component:

$$V \propto I$$

if the temperature of the component is constant.

a) Explain the mathematical statement $(V \propto I)$ given for Ohm's lav

The equation form of Ohm's law is:

$$V = IR$$

A bulb in an electrical circuit has $2.30\ \mathrm{A}$ flowing through it and has a

b) Calculate the potential difference across the bulb.

21. A student has a set of 140 square dice. The student rolls the dice and with the number 4 facing upwards. The student rolls the remaining c

Explain why this process is a useful model for representing the rando radioactive decay.

22. All masses produce a gravitational field and this field exerts a force o that enter this field.

The force between can be determined using the following equation:

$$F = -\frac{GMm}{r^2}$$

where M is the mass of the larger of the two masses, m is the mass c distance between the two masses and G is the gravitational constant

a) Estimate the gravitational force between Earth and the Moon ($m_M = 7.35 \times 10^{22}$ kg, $M = 6.00 \times 10^{24}$ kg, $r = 4.00 \times 10^{8}$ m).
b) Give your answer to (a) in kN.
c) Write your answer to (a) to 2 significant figures.

CHAPTER 3: BASIC MATHS SKILLS

This chapter will simply recap the basic maths skills required for this cour
you are comfortable with these skills before tackling the further maths ski
familiar from GCSE, Year 9 and Year 8 Maths courses.

SKILL B1: UNITS, CONVERSION BETWEEN UNITS AND OF

Part A: Specification Overview

The course will expect you to be able to identify and use appropriate units
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 usec

When calculating physical quantities in this course you will need to include
The units will not be given to you and you will be expected to recall the SI

Any calculation involving quantities with units that aren't SI base units w
the units or be able to derive them from the SI base units.

The following SI base units and their corresponding physical quantities ar

Physical Quantity	SI Base Units	Commo
Mass	kilogram	
Time	second	
Luminous intensity	candela	
Thermodynamic temperature	kelvin	
Length	metre	
Electric current	ampere	
Amount of a substance	mole	

You will be expected to present physical quantities in their SI base units ur
For example, if you are using distance and time to determine velocity, the
quantities must be in metres and seconds respectively to perform the calcu

Conversion between units

You will also have to be able to convert between units. You may be given
magnitude and need to convert back to the SI unit in order to perform the

Prefixes can be used to convert between units in different orders of magni
which is used before the unit to let you know the order of magnitude.

Prefix	Orde
pico (p)	
nano (n)	
micro (μ)	
milli (m)	
centi (c)	
deci (d)	
kilo (k)	
mega (M)	
giga (G)	
tera (T)	

Part C: Worked Example

A family car travels 8.00 km in 10.0 minutes. The velocity of the car is g

Calculate the velocity of the car during the 10.0 minutes, giving your an

Solution:

1. First, you will have to notice that the time and the displacement are n
   therefore you will have to convert the units before performing the cal

   $s = 8.00\text{ km}$

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

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

   $t = 10.0\text{ minutes}$

   1 minute = 60 seconds

   therefore, in SI base units, $t = (10.0\times60) = 600\text{ s}$

2. Now all the quantities used in the calculation are in SI units and the c

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

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

   $v = 13.333... = 13.3\text{ ms}^{-1}$ (3 s.f.)

Part D: Practice Questions

1. Select the SI base unit for mass from the following options:
A. cd
B. kg
C. K
D. M

2. State the SI units for the following physical quantities:
a) Mass
b) Thermodynamic temperature
c) Length
d) Amount of substance

3. The National Grid supplies electricity to our homes.

The cables used to transmit electricity lose around 188 kW of power d

Convert the power loss into watts (W).

4. A cylindrical canister is used in a physics investigation into the prope

The physicist needs to calculate the volume of the cylinder to carry ou

- The radius of the cylinder's circular face is 10 cm and it has heigh
- The volume for a cylinder is given by the equation $V = \pi r^2 h$.

Calculate the volume of the cylinder in cubic metres.

SKILL B2: USE AND CALCULATE QUANTITIES IN DI

Part A: Specification Overview

The exam board will expect you to be able to identify and work with expr standard form.

You will be tested on your ability to use, calculate and present physical qu forms.

This knowledge and skill will be tested throughout each of the topics for t

Part B: Theoretical Overview

Decimal Form:
A decimal is a fraction written in an alternative form. It can be identified

An example of a decimal form would be:

$$3.4$$

where the 3 is in the units column and the 4 is in the 10ths column. It can t '3 and 4 10ths'.

Standard Form:
The number N can be said to be in standard form if it is written in the fol

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

S represents a number no smaller than 1, and less than 10, and x, if positi times the number N has been multiplied by 10 and, if negative, how mar been divided by 10.

Standard form is used as a more convenient way of representing numbers very small.

For example:

- The number 147,000,000,000 could be written more conveniently in its
- The number 0.00000000236 could be written more conveniently in its

You will be expected to recognise and convert numbers into these two for calculations.

To convert to standard form:

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

   e.g. 70,000

   7.

2. Then determine how many times your first digit has been multiplied original number.

   e.g. $7 \times 10 \times 10 \times 10 \times 10 = 70\ 000$

   Therefore, 7 has been multiplied by 10 four times.

3. To write it in standard form, you take the number of times your digit 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 a 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 div 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 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 like before.

   e.g. 4.5×10^{-3}

Part C: Worked Example

1. The mass of Earth is $M = 5\ 972\ 000\ 000\ 000\ 000\ 000\ 000\ 000$ kg a $r = 6.37\times10^6$ km .

The gravitational constant G is given by $G = 6.67\times10^{-11}\ \text{Nm}^2\,\text{kg}^{-2}$.

The equation for the gravitational potential is $E_{\text{grav}} = -\frac{GM}{r}$

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

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

Solution:

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

$M = 5.97\times10\times10\times10\times10\times10\times10\times10\times10\times10\times10\times10\times10\times10\times$

$\ldots\times10\times10\times10\times10$

5.97 has been multiplied by 10 twenty-four times

$M = 5.97\times10^{24}$ kg

b) $E_{\text{grav}} = -\frac{GM}{r}$

$$E_{\text{grav}} = -\frac{(6.67 \times 10^{-11}) \times (5.97 \times 10^{24})}{(6.37 \times 10^{6})}$$

$E_{\text{grav}} = -62511616.95$ J

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

6.25 has been multiplied by 10 seven times

$E_{\text{grav}} \approx -6.25 \times 10^{7}$ J

Part D: Practice Questions

1. Give the following numbers in standard form:

a) 2,570,000
b) 0.00236
c) 369
d) 0.0581

2. Convert the following numbers out of standard form to a decimal nun

a) 4.78×10^{7}
b) 1.2×10^{-3}
c) 7.63×10^{4}
d) 6.33×10^{-14}

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

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

A 8.30×10^{3} kg lorry travels with velocity of $11.0\ \text{ms}^{-1}$.

a) Give the mass of the lorry as a whole number.
b) Calculate the kinetic energy of the lorry travelling at $11.0\ \text{ms}^{-1}$, giv standard form.

SKILL B3: ESTIMATION

Part A: Specification Overview

This Physics course will require making appropriate estimates of physical
within your calculations. Additionally, your estimation skills will be furtl
questions when you will be expected to estimate the effects of varying exp

This skill is tested throughout the course.

Part B: Theoretical Overview

In the course you might not always be provided with the numerical value
required for a calculation. The exam board, in this case, would then expe
understanding of the course by making appropriate estimates of quantitie

The exam board won't expect you to be able to estimate a physical quantit

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 an adult	2 m
Speed of sound	$300\ \text{ms}^{-1}$
Pressure of the atmosphere	100,000 Pa
Density of water	1,000 kg m
Speed on motorway	30–40 ms
Speed of plane	$300\ \text{ms}^{-1}$
Power of a car	60 kW
Power of a person	100 W
Distance to Sun	150,000,000
Distance to Moon	400,000 kr
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:**

$$E_{\text{grav}} = mgh$$

where m is the mass of the object, g is the acceleration due to gravi object is lifted through.

The gravitational potential energy is defined as the energy stored b lifted through a height h.

A diver is standing at the end of a 5 m diving board. The accelerati $g = 9.81\ \text{ms}^{-1}$

a) Estimate the mass of an average adult
b) Based on a), estimate the gravitational potential energy E_{grav}
c) Predict what would happen to your answer to (b) if the diver w 10 m board instead.

Solution:

1. a) 70–80 kg
   b) $E_{\text{grav}} = mgh$
   $E_{\text{grav}} = (70 - 80) \times 9.81 \times 5$
   $E_{\text{grav}} = 3000 - 4000\ \text{J}$
   c) Since $E_{\text{grav}} \propto h$, if h doubles then we can estimate that E_{grav} will a

Part D: Practice Questions

1. A car is travelling for 10,000 seconds at an average speed on a motorv

   The equation to determine the distance travelled by the car is $d = s\times$

   Estimate how far the car has travelled in 10,000 seconds.

2. Two planes are travelling with average speed to their respective desti

   Plane 1 travels for 10,800 seconds and Plane 2 travels for 14,400 secon

   Estimate the difference between the distances travelled by Plane 1 an

   Note: $d = s \times t$

3. The gravitational potential at a distance r from a planetary object is:

$$E_{\text{grav}} = -\frac{GM}{r}$$

where M is the mass of the planetary object, r is the distance from it G is a gravitational constant 6.67×10^{-11} Nm²/kg²

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

Skill B4: Significant figures

Part A: Specification Overview

The specification states that you should be able to use an appropriate num
when presenting numbers or measured values.

Specifically, they want to see you demonstrating ability to:

- present calculations to an appropriate number of significant figures g numbers of significant figures
- demonstrate that calculated quantities can only be presented to the li measured value

Part B: Theoretical Overview

Significant figures are used to round numbers. When calculating quantiti provide a detailed value for a quantity, and sometimes an approximation 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 s
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
0.0040	1st significant figure = 4 2nd significant figure = 0

You should start to see the pattern, and also realise that the most significant non-zero term. If a zero appears in the value between numbers then it coun of its value as a placeholder. A zero at the end of a value is also significant a

If you are told to provide a measured quantity to x significant figures you following steps:

1. Identify your x^{th} significant figure.
2. Round up if the number after the x^{th} significant figure is 5 or above, c number after the significant figure is 4 or below.
3. Then set all the numbers that follow the significant figure before a de any trailing decimal figures after the last significant figure.

For example, if you were given $F = 38.37654\ \text{N}$, you might not need to kno 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 t
3. The number to 3 significant figures will then be 38.4 N (since the zero should not write 38.40000 N).

Note: When rounding a measured value to significant figures you cannot (a more accurate measured value) than the values you are given to calcula More specifically, the number of significant figures given in an answer sh number of significant figures in any value used in the calculation.

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 suspensi the bridge is stable and safe they need to determine the stress actin**

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

   where σ represents stress, F represents the force exerted on the ol sectional area of the object.

   The group of engineers know that force acting on one cable is 85,36 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 σ = 123723.52**
   - **c) Write your answer to (a) to 3 significant figures.**

Solution:

1. 50,210,000

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

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

   $\sigma = 123723.5275$

   $\sigma = 123723.53$ Pa or N/m^2

   b) Since the calculated result σ cannot be more accurate than the m used in the calculation, the answer can only be given to 3 signific

   c) 124,000

Part D: Practice Questions

1. Choose the number below which is 345,700 written to 2 significant fig
   - A. 340,000
   - B. 34
   - C. 350,000
   - D. 345,700

2. Give 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 r cables of 1.60 A and a potential difference of 2.63 V across them. Fror engineer calculates the resistance to be 1.64375 Ω. What is wrong wit

4. The Space Shuttle requires an enormous resultant force of 10,500,000 The shuttle has a mass of 2,220,000 kg.

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

   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 obta
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
accurate measurement of the value by reducing the contribution of errors
value (or an average value) would then be required if the measured value
other physical quantities involved in the experiment.

Let's say you had N measurements. The equation for calculating the mea

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

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 electri
measures the resistance of a resistor. The student repeats the measurem

Resistance (Ω)						
r_1	r_2	r_3	r_4	r_5	r_6	r_7
2.43	2.24	2.41	2.36	2.33	2.27	2.42

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 temperatur
in kelvin:

T_1	T_2	T_3	
77.0	76.0	75.0	7

a) Explain how the physicist could determine the average value obt

b) Calculate the mean value for the temperature of liquid nitrogen.

2. The transport department released statistics on the speed of cars outs
five different cars is given below:

Car 1	**Car 2**	**Car 3**	**C**
30.0 mph	40.0 mph	20.0 mph	22.0

Calculate the mean value for the speed from this sample.

SKILL B6: USE CALCULATOR TO HANDLE SIN, C

Part A: Specification Overview

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

Using your calculator to handle the trigonometric functions will be assessec with vectors and projectile motion, but expect it to also appear at various pc

Part B: Theoretical Overview

When working with calculations involving trigonometric functions alway is asking you to work in degrees or radians. Ensure you set your calculat accordingly before continuing with the calculation.

Part C: Worked Example

1. **During an investigation into the critical angles of different material critical angle of Material 1 was 39.9°.**

   The equation relating the critical angle and the refractive index of a

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

   where C is the critical angle and n is the refractive index of the mat

   a) **Use this equation to determine the refractive index n of Materi**

   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 calcula

1 [÷] [sin] 39.9 [=]

Following those steps will display an answer of 1.56 on your calculat

Therefore,

$n = 1.56$

Note: Make sure your calculator is set to degrees

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

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

$\sin C = 0.7518...$

$C = \sin^{-1}(0.7518...)$

To evaluate C, proceed with the following steps, using the buttons or

shift *sin* *Ans* =

Note: Tl
last an

Following those steps will display the answer 48.7534… on your calcu

Therefore,

$C = 48.8°$ (3 s.f.)

Part D: Practice Questions

1. State the solutions to the following equations. Assume that each equa
a) $\sin 0.56$
b) $\cos 78$
c) $\tan 14$

2. Determine x in the following equations. Assume that each equation i
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 ca

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

where x is the displacement, A is amplitude, ω is angular frequency
oscillation.

A bungee jumper will undergo simple harmonic motion during their

The angular frequency of the jumper is 1.30 rad s^{-1} and the amplitude

Calculate the displacement of the jumper after 30 seconds.

SKILL B7: USE CALCULATOR TO WORK WITH POW

Part A: Specification Overview

You will be expected to determine and use power functions during calcul
This skill will be tested in various topics throughout this course; however,
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 v

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 v
However, this proves to be a little harder as you will have to invert the po

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
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 ca
of 16, which essentially means you are looking for a number that equals 1(

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 ma closest to the Sun. The maximum speed of Halley's comet is appro 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

The kinetic energy of another comet is calculated to be $E_k = 1.$ mass of 1.30×10^{14} kg

b) Show by calculation whether this comet has a lower or greater 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

4 [$x^{\square}$] 3 [+] 1

Following the steps above will display an answer of 65 in your calcul

Therefore,
$x = 65$

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

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

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

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

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

$v = 1.45 \times 10^4$ 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 poten

The equation for calculate elastic potential energy is:

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

Calculate the elastic potential energy (E) of a spring with a spring co when it is stretched (x) by 0.020 m.

3. A group of Year 11 physicists were conducting experiments into the e The group measured the potential difference (V) across a 10.0 Ω resis

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 resi

Calculate the power dissipated by the resistor.

4. A car accelerates (a) at 2.8 ms^{-2} and covers a distance (s) of 15.8 m. at a velocity (u) of 2.3 ms^{-1}. Calculate the final velocity (v) of the ca distance, using the equation $v^2 = u^2 + 2as$.

SKILL B8: CHANGING THE SUBJECT OF THE I

Part A: Specification Overview

Your ability to change the subject of a formula is essential for success in th

The skill is continually assessed throughout each and every topic. A comp your speed and accuracy in answering questions.

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

Part B: Theoretical Overview

To change the subject of the formula you will use inverse operations to ma 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 v y-intercept c.

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

1. Initially you would want to bring all the variables that aren't c to one 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 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 en

$$c = y - mx$$

   The equation can now be used as a tool to determine the value for the

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

Part C: Worked Example

Particle accelerators are used by hospitals in radiotherapy treatment to c accelerated between charged plates that increase their speed.

The equation relating the work done on the particle and the kinetic ene below:

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

where e is the charge of the particle, V is the potential of the charged p particle and v is the final speed of the particle.

To ensure accelerators are operating correctly, a medical physicist wants the particles.

Rearrange the formula so that it is in a more appropriate form to determ 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 sid
   - v is initially divided by 2, and therefore to move 2 to the other si 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 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; further inverse operation:
   - v is squared in its current form, and therefore to get v by itself v both sides

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

   Now v is the subject of the formula and the formula is now in a form determine the final speed of the particles.

Part D: Practice Questions

1. Choose which of the equations below shows the equation $tx = 2 + p$ r
subject is 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,

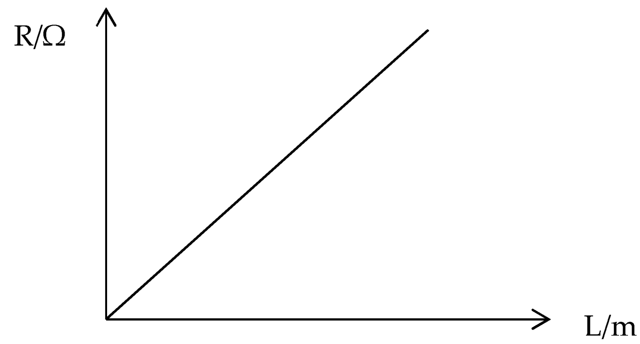
rearrange the formula so that I is the subject.

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

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

where R is resistance, ρ is resistivity, L is length and A is the cross

a) Rearrange the equation to make the resistivity ρ of a material th



The resistive properties of a material were investigated in a laborator

Physicists used the graph to determine that the gradient (m) of the li

b) Rearrange the equation for the gradient to solve for ρ.

4. The equation for determining the intensity of radiation from a point s

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

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

A physicist wants to determine how far away (r) the star she is stud

Rearrange the equation so it is in a more convenient form to calculate

SKILL B9: SOLVING ALGEBRAIC EQUATIONS, INCLUD

Part A: Specification Overview

Solving algebraic equations forms the basis to solving all calculations in th
required to substitute values for variables into algebraic equations and sol

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 t
of changing the subject of the formulas.

An algebraic equation simply refers to any equation where one or more va
unknown.

To solve the algebraic equation:

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

   This will require you to use inverse operations.

   Note: If the variable you want to find is already the subject then you

2. Secondly, insert in the values for variables you have and work throug
   unknown.

Part C: Worked Example

1. **The mass of Earth is $M_E = 5.98\times10^{24}$ kg and the mass of a geostatic**

   The orbital radius of a geostationary satellite is roughly 42,157 km a
   G is $6.67\times10^{-11}\,\text{Nm}^2\text{kg}^{-2}$.

   The equation for gravitational potential energy for the system is:

   $$E_{\text{grav}} = -G\frac{M_1M_2}{r},$$

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

   Calculate the gravitational potential energy for the system (E_{grav}) of

Solution:

1. We do not need to rearrange the formula as E_{grav} is already the subject
2. Insert in the numerical values for the variables into the equation and t

   $E_{\text{grav}} = -G\frac{M_EM_S}{r}$

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

   $E_{\text{grav}} = -(6.67\times10^{-11})\times(3.546267524\times10^{19})$

   $E_{\text{grav}} = -2\,365\,360\,438\text{ J} = -2.37\times10^9\text{ J}$

Part C: Worked Example

2. **A runner in a relay race starts to increase their speed before they rec not start running from standing still. When the baton is passed to th at 0.24 ms^{-2} over 100 m, and cross the finish line with a speed of 8 ms**

   The equation $v^2 = u^2 + 2as$ relates the runner's final velocity, v, initia and distance travelled, s.

   Calculate the speed the runner was travelling at when they receivec

Solution:

1. To make u the subject of the equation, we need to rearrange it using i Starting with $v^2 = u^2 + 2as$, we can subtract $2as$ to isolate u^2:

$$u^2 = v^2 - 2as$$

   Because we have u^2 but need u, we have to take the square root of bot

$$u = \sqrt{v^2 - 2as}$$

2. Insert in the numerical values from the question to find u:
   $u = \sqrt{8^2 - 2 \times 0.24 \times 100}$
   $u = \sqrt{64 - 48}$
   $u = \sqrt{16}$
   $u = 4$ ms^{-1}

Part D: Practice Questions

1. The equation for potential difference is $V = IR$, where I is current ar

Calculate the potential difference across a 10 Ω resistor with a current

2. An equation for current flowing in a conductor is given by $I = Anev$, area of the conductor, n is the number density of copper atoms, e is is the drift velocity of the electrons.

An electrician detects 1.20 A of current flowing in a copper wire with $2.34\times10^{-7}\ \text{m}^2$. The number density of copper atoms is $8.50\times10^{28}\ \text{m}^{-}$

Calculate the drift 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 actir of an object, v is its final velocity, u is its initial velocity and t is the is acting.

A $7.1\times10^{7}\ \text{kg}$ train leaves the platform at a velocity of $0.44\,\text{ms}^{-1}$. The 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 cir a corner the centripetal force is supplied by the frictional force betwee

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

The centripetal force is 50 N, the mass of the car is 670 kg and the radi

Determine the speed at which the car would have been travelling as i

Skill B10: Absolute uncertaint

Part A: Specification Overview

As a Physics student you will have to be able to recognise uncertainties in
and use techniques to determine an uncertainty when data is added, subtr
raised to powers.

Part B: Theoretical Overview

An uncertainty is a value that is associated with a measurement to illustra
measurement can realistically fall within when the experiment errors are
gives an indication of the range of values in which the true value lies.

For example, the measurement 2.5 ± 0.1 N indicates that the true values w
2.4 N (2.5 – 0.1) and 2.6 N (2.5 + 0.1).

Let's say you have measured two parameters a, b and have determined t
Δa and Δb respectively from the equipment you used to measure them:

$$a \pm \Delta a; b \pm \Delta b$$

Uncertainties can also be represented as a percentage uncertainty ε_a *and*

$$a \pm \varepsilon_a; b \pm \varepsilon_b$$

You will learn more about the percentage uncertainty in the following ski

You may then be asked to calculate further quantities involving these two
When doing so, you not only have to take into consideration the two vari
absolute uncertainties and percentage uncertainties.

The following rules illustrate how to combine uncertainties when differen
the variables:

Two variables added together:	$(a \pm \Delta a) + (b \pm \Delta$
Two variables subtracted from one another:	$(a \pm \Delta a) - (b \pm \Delta$
Two variables multiplied together:	$(a \pm \varepsilon_a) \times (b \pm \varepsilon_b$
Two variables divided by one another:	$(a \pm \varepsilon_a) \div (b \pm \varepsilon_b$
A variable raised to the power of n:	$(a \pm \varepsilon_a)^n = (a^n +$

Part C: Worked Example

1. **The equation relating *a*, *b* and *c* is as follows: $a = b + c$. The values**
$b = 30.5 \pm 0.2$ N and $c = 5.3 \pm 0.1$ N .

   Calculate the value of *a*, including its absolute uncertainty.

2. **A pupil wants to know the length of wire used in a circuit; he meas**
obtains the following measurements:

$$l_1 = 13 \pm 1 \text{ cm}; l_2 = 12 \pm 1 \text{ cm}$$

   Determine the total length of the wire.

3. **A medical physicist wants to know the combined volume of the tw**
The medical physicist measures the volume of the right lung to be
volume of the left lung to be $V_l = 5950 \pm 250 \text{ cm}^3$

   Determine the combined volume of both lungs.

Solution:

1. $a = (b \pm \Delta b) + (c \pm \Delta c)$
$a = (b + c) \pm (\Delta b + \Delta c)$

   In this case, you can simply use the absolute uncertainties when comb
and c since they both have the same units.

   $a = (30.5 \pm 0.2) + (5.3 \pm 0.1)$
$a = (30.5 + 5.3) \pm (0.2 + 0.1)$
$a = 35.8 \pm 0.3$ N

2. a) $l = l_1 + l_2$
$l = (13 \pm 1) + (12 \pm 1)$
$l = (13 + 12) \pm (1 + 1)$
$l = 25 \pm 2$ cm

   In this case, you can simply use the absolute uncertainties when
the same units.

3. $V = \left(V_r \pm \Delta V\right)_r + \left(V_l + \Delta V_l\right)$
$V = \left(V_r + V_L\right) \pm \left(\Delta V_r + \Delta V_L\right)$
$V = \left(6100 + 5950\right) \pm (100 + 250)$
$V = 12050 \pm 350 \text{ cm}^3$

Part D: Practice Questions

1. State the absolute uncertainties of the following measurements:

a) 4.55 ± 0.05 A

b) $16.2 \pm 0.1\ \text{ms}^{-1}$

c) 3626 ± 4 J

2. The equation for total potential difference across a circuit is given by

A student measures the potential difference across a resistor to be V_1 = difference across a bulb to be $V_2 = 230 \pm 0.1$ V .

Calculate the total potential difference across the circuit using the equ account the absolute uncertainties.

SKILL B11: PERCENTAGE UNCERTAINTY AND PERCEN

Part A: Specification Overview

The exam board will expect you to be able to work with percentage uncer
absolute uncertainty.

Part B: Theoretical Overview

Percentage Uncertainty

A percentage uncertainty is simply an alternative way of illustrating the u
A percentage uncertainty displays the absolute uncertainty of a measured
measured value.

The equation for determining the percentage uncertainty of a measured v

$$percentage\ uncertainty = \frac{absolute\ uncertainty}{measured\ value} \times$$

In other words,

$$\%\ uncertainty\ in\ A = \frac{\Delta A}{A} \times 100\%$$

Conversely, you can also determine the absolute uncertainty of a measure
percentage uncertainty:

$$absolute\ uncertainty = \frac{percentage\ uncertainty}{100\%} \times meas$$

In other words,

$$\Delta A = \frac{\%\ uncertainty\ in\ A}{100\%} \times A$$

The percentage uncertainty is important when combining uncertainties th
uncertainties are in different units, e.g. joules and watts, you cannot comb
but you can combine their percentage uncertainties.

For example, if you were asked to determine the value for power P giver
combine the uncertainties of I and V to find the uncertainty in P.

However, in this case I and V do not share the same units, so you will h
percentage uncertainties, using the combination rule (see previous skills)
uncertainties.

Percentage Change

The percentage change is different to the percentage uncertainty; it repres
original measurement and a repeated measurement to indicate the decrea
measurements as a percentage.

The equation for determining the percentage change between two measur

$$percentage\ change = \frac{|\ new\ value - original\ value\ |}{original\ value}$$

Note: The modulus sign (| |) on the top of the fraction simply takes into a
dealing with a negative if there has been a decrease (new value < original

The modulus sign ensures you take the absolute value of the difference, a
top of the fraction will always be positive.

Part C: Worked Example

1. **The mass of an object is measured to be $\mathbf{0.30 \pm 0.05\ kg}$, using a set o**

   Calculate the percentage uncertainty of this measurement.

2. **A Year 11 student is carrying out an experiment to investigate the m frictionless ramp. The student calculates the final velocity of the ca ramp, to be $v = \mathbf{2.4 \pm 0.1\ ms^{-1}}$. The student increases the steepness final velocity again, this time obtaining $v = \mathbf{2.8 \pm 0.1\ ms^{-1}}$.**

   a) Calculate the percentage uncertainty of the student's initial me
   b) Calculate the percentage change in the measurements of final v

Solution:

1. $$percentage\ uncertainty = \frac{0.05}{0.3} \times 100\%$$
   $$percentage\ uncertainty = 16.7\ \%$$

2. a) $$percentage\ uncertainty = \frac{0.1}{2.4} \times 100\%$$
   $$percentage\ uncertainty = 4.2\ \%$$

   b) $$percentage\ change = \frac{|2.8 - 2.4|}{2.4}$$
   $$percentage\ change = 16.7\%$$

Part D: Practice Questions

1. Calculate the percentage uncertainty of 2.6 ± 0.2.

2. Calculate the percentage change between the two values, with the ne value 4.6.

3. The frequency of an oscillating pendulum was measured in an invest due to gravity (g). The value for frequency obtained was 5.2 ± 0.05 H

a) Calculate the percentage uncertainty of this measurement.

The length of the pendulum was altered and the experiment repeated measured as 6.4 Hz after this alteration.

b) Calculate the percentage change in the frequency.

4. Power in a circuit can be determined by the equation $P = IV$. During technician measured the current, *I*, to be 0.21 ± 0.05 A and the poten the electrical component in the circuit to be 5.6 ± 0.1 V.

Calculate the power in the electrical component.

5. A tennis ball is measured to travel at an average speed of $v = 157 \pm 1$ r The mass of the tennis ball is given by $m = 0.059 \pm 0.001$ kg

The kinetic energy of an object is $E_K = \frac{1}{2}mv^2$, where m is the mass o of the object.

Calculate the kinetic energy of the tennis ball.

SKILL B12: ANGLES

Part A: Specification Overview

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

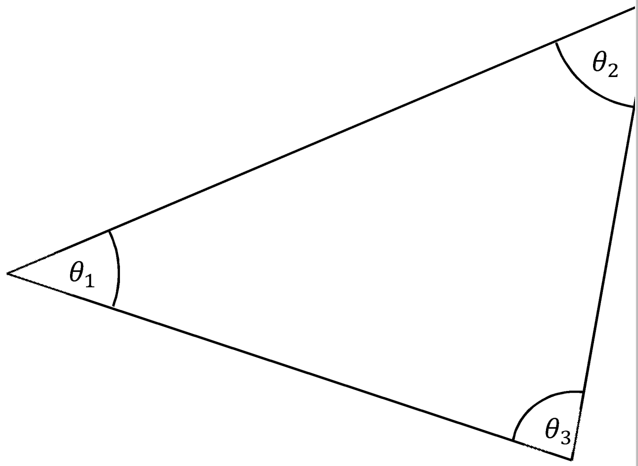
You will be required to make use of this skill throughout the course but th
tested when working with force diagrams and vector resolution questions

Part B: Theoretical Overview

To interpret and understand physical problems and applications, you will
knowledge of angle rules within circles and triangles.

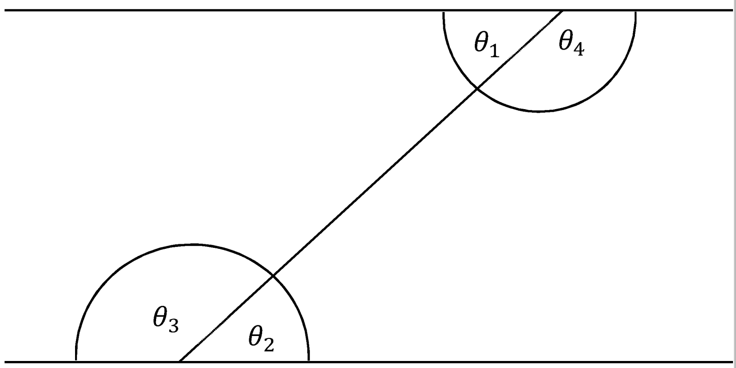
Knowledge of the following angle rules is essential when analysing physi

- The angles inside a triangle



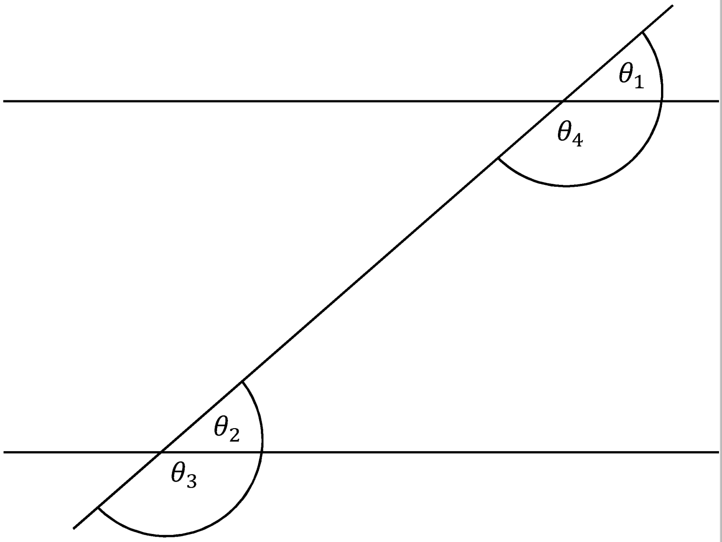
$$\theta_1 + \theta_2 + \theta_3 = 180°$$

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



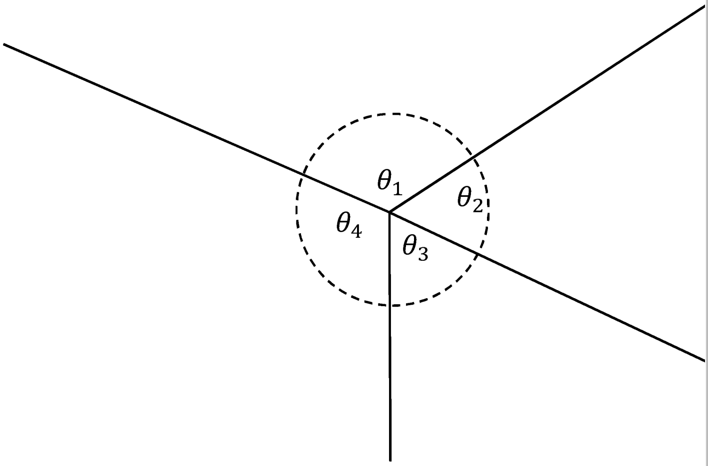
$$\theta_1 = \theta_2$$
$$\theta_3 = \theta_4$$

- the corresponding angles are equal



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

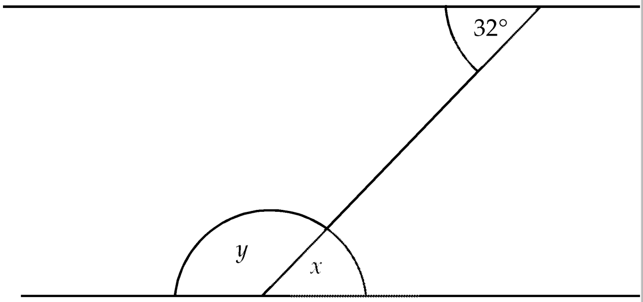
- All angles that meet at a point must add up to 360°



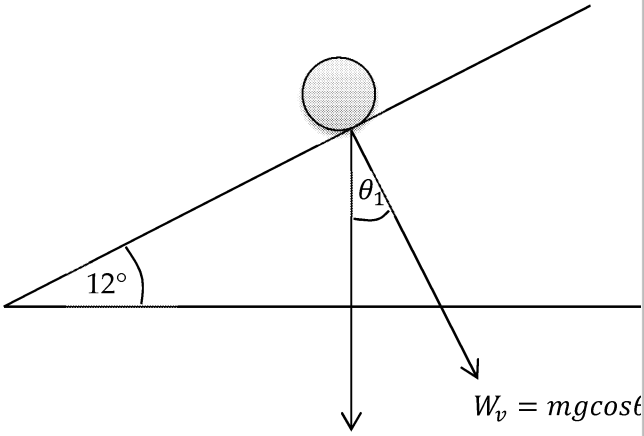
$$\theta_1 + \theta_2 + \theta_3 + \theta_4 = 360°$$

Part C: Worked Example:

1. **Calculate the missing angles x and y.**



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

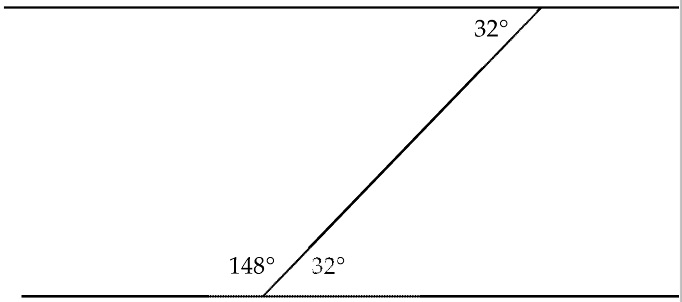


In order to calculate the component of weight perpendicular to the
to be evaluated.

a) **Calculate the value of θ_1 using your knowledge of angles on pa**
b) **Write the expression for W_v in terms of θ_1 found in (a).**

Solution:

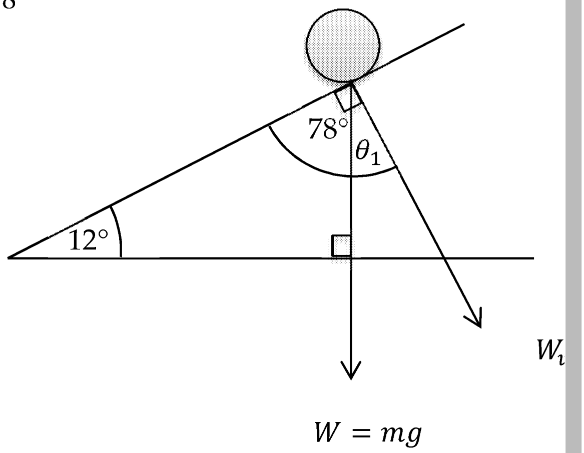
1.



- 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°. Th
  $y = 180 - x = 180 - 32 = 148°$

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

Therefore, the remaining angle of the triangle created by W and t
$180° - (12° + 90°) = 78°$



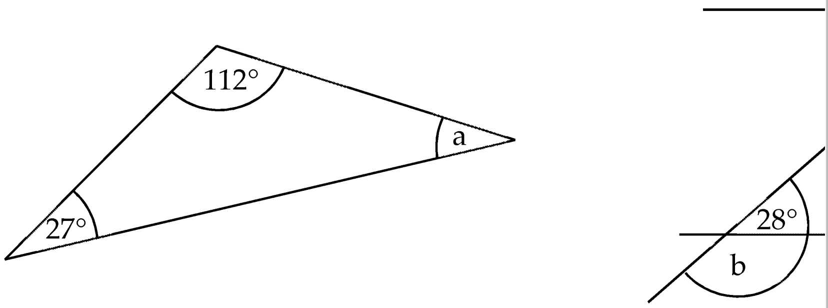
Then, since W_v is perpendicular to the slope of the inclined plane
the slope is 90°.

Therefore, θ_1 can be found from,
$\theta_1 = 90 - 78 = 12°$

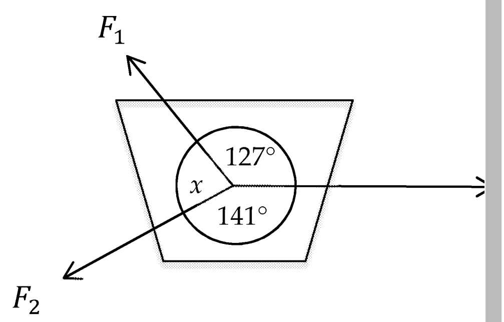
b) $W_v = mg\cos\theta_1$
$W_v = mg\cos 12°$

Part D: Practice Questions

1. Determine the missing angles.



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 A

Part A: Specification Overview

The specification states that as a physics student you should be comfortab between degrees and radians and be able convert from one form to the otl

You will be expected to be able to demonstrate this skill in vector resoluti 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 an comfortable with degrees as the unit of angles in a circle, but radian is sim the same value.

It is similar to measuring the length of a variable; we can measure in miles Let's say you have an angle in degrees and you want to convert it into rad 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 conve would use the following equation:

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

Note: When dealing with angles greater than 360° or 2π, just divide the a remainder as your new angle to keep it within the standard range.

Part C: Worked Example

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

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 incide boundary is measured to be 0.64 radians.

b) Calculate the angle of incidence in degrees.

Solution:

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

$1.169... = 1.2$ radians (2 s.f.)

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

$= 36.67°$

$= 37°$

Part D: Practice Questions

1. Choose the angle below which 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 chang

The critical angle, given by $\sin C = \frac{1}{n}$, is the specific incident angle at

from refraction to total internal reflection, changing direction and refl
a medium.
The refractive index (n) is 1.52.

Calculate the critical angle in degrees.

SKILL B14: VISUALISING AND REPRESENTING STRUCTURE

CALCULATING AREAS AND VOLUME

Part A: Specification Overview

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

This skill will be crucial when working on physical problems. The skill w determining physical properties of the problem. You will see this skill tes pressure, and resistivity topics.

Part B: Theoretical Overview

Area

This course will require you to calculate the following areas using the foll

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:

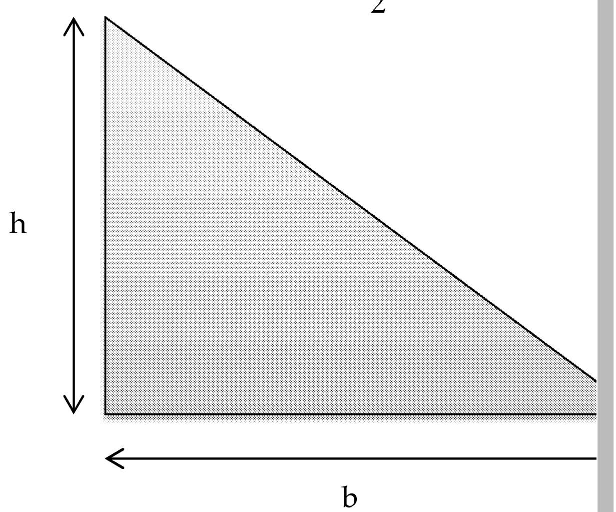
  $A = \pi r^2$

  or

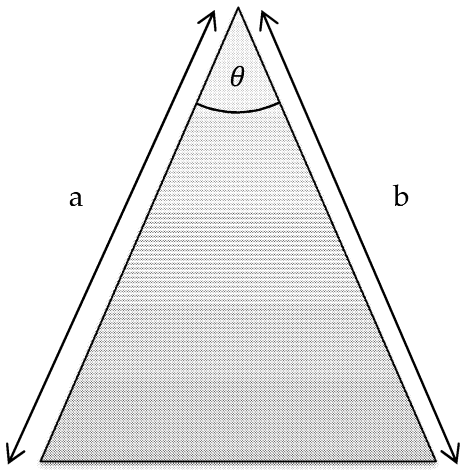
  $A = \pi \left(\frac{d}{2}\right)^2$

Triangle:

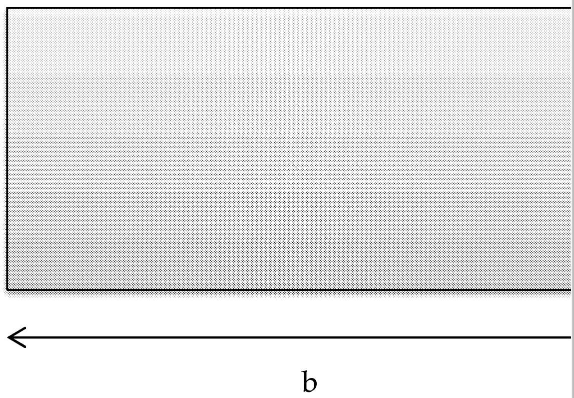
- The area of a right–angled triangle is given by: $A = \frac{1}{2} \times b \times h$



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



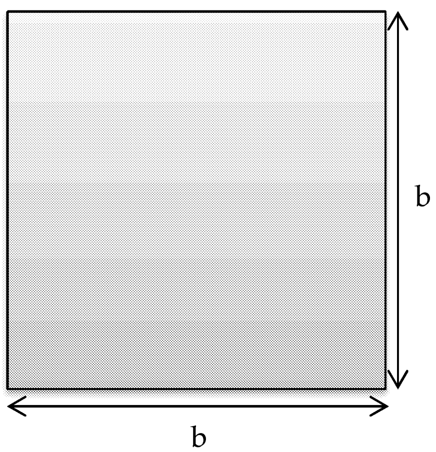
Square/Rectangle:



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:

The surface area of a 3D shape is the sum of all the areas on the outer face
flat, while some are curved for shapes such as cylinders and spheres.

> **Note**: The equation for surface area depends on the shape; for a cylinder,
> the surface area will include the equation for the area of a circle, whereas
> area of a rectangular block will include the equation for the area of differ

Volume:

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

$$V = A \times h$$

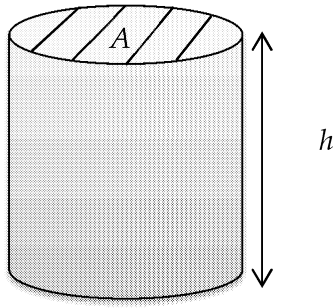
where A is the surface area of one of the sides of the shape and h is the hei

Cylinder

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

$V = A \times h$

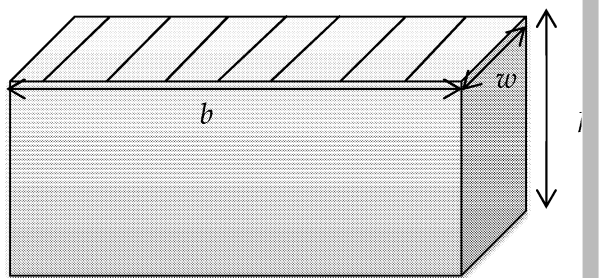
$V = (\pi r^2) \times h$



Rectangular block

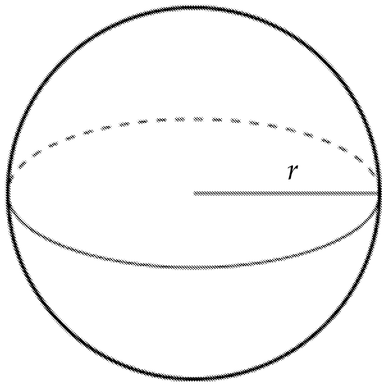
$V = A \times h$

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



Sphere

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



Part C: Worked Example

1. **Calculate the cross-sectional area of a cylinder with radius $r = 1.6$ m**

2. **An energy company is wanting to determine the resistivity of the w its machines.**

   The resistivity of a wire can be determined using the following equ

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

   where ρ is the resistivity of the material, R is the resistance of the sectional area and L is the length of the material.

   The wires used are cylindrical in shape, with a radius of 2.0 mm an resistance of the wires is known to be 0.01 Ω, calculate the resistivit

Solution:

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

$A = \pi r^2$

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

$A = 8.0424... = 8.0\ \text{m}^2$ (2 s.f.)

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

$$\rho = \frac{0.01 \times A}{(100 \times 10^{-2})}$$

Therefore, before the equation can be used to determine ρ, the cross-s be evaluated.

The cross-sectional area of a cylindrical object is a circle. Therefore:

$A = \pi r^2$

$A = \pi \times (2 \times 10^{-3})^2$

$A = 1.2566 \times 10^{-5}\ \text{m}^2$

Therefore, the resistivity of the wire is:

$\rho = \dfrac{0.01 \times (1.2566 \times 10^{-5})}{(100 \times 10^{-2})}$

$\rho = 1.3 \times 10^{-7}\ \Omega\text{m}$

Part D: Practice Questions

1. A cylindrical barrel is being used in an experiment that investigates tl
To carry out the experiment, the volume of the barrel needs to be kno
and a length of 0.63 m.

a) Calculate the volume of the barrel.

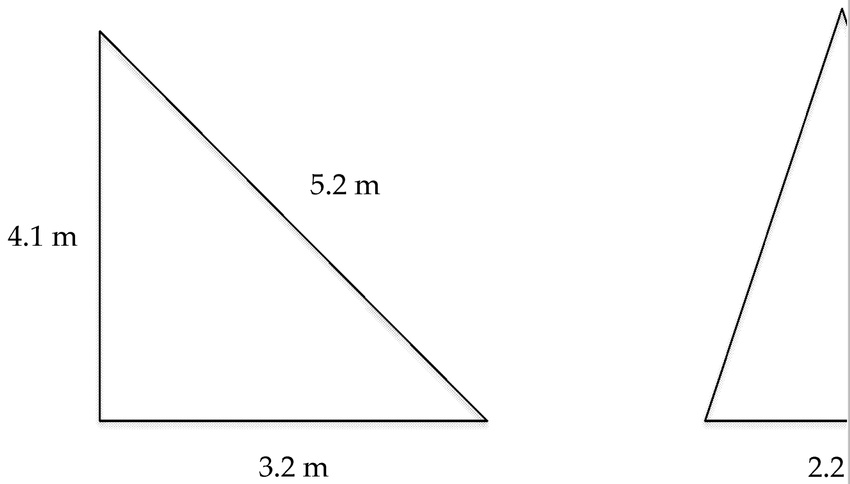
b) Calculate the circumference of the barrel.

The experiment is repeated with a rectangular trunk with dimensions

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 flo

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

The equation for determining the buoyancy force (B) acting on the b

$$B = \rho V g$$

where V is the volume of the displaced fluid (in this case seawater), g
gravitational field strength, and $\rho = 1020\ \text{kgm}^{-3}$ is the density of the

Using the equation, calculate the buoyancy force acting on the box, us

SKILL B15: MATHEMATICAL SYMBO

Part A: Specification Overview

The exam board will expect you to understand and use the symbols: =,<,
be tested on your ability to recognise the significance of these symbols in r
and work with the expressions to find numerical solutions.

This skill will be tested in every topic in this course; therefore, a grasp of thi

Part B: Theoretical Overview

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

Symbol	Meaning	Context
=	Equal to	$x = 3$
<	Less than	$5 < 7$
≪	Much less than	$1 \ll 10{,}000$
≫	Much greater than	$785 \gg 0.02$
>	Greater than	Velocity 1 > Velocit
∝	Proportional	Force ∝ accelerati
≈	Approximately equal	$1.234 \approx 1.233$
Δ	Change in	ΔT

Part C: Worked Example

It can be said that during a collision or impact the net force exerted is give

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 $F \propto \dfrac{\Delta p}{\Delta t}$ reads 'Net force is proportional to the change in n
change in time'. Therefore, it can be said that if there is a greater net force
be a proportionally greater change in momentum divided by change in tir

Part D: Practice Questions

1. State if each of the following statements is true or false:

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

B. $F \approx m$; '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 down the following statements in terms of their mathematical s

a) Pressure is proportional to force

b) V_1 is much less than V_2

c) B is greater than C

3. Researchers at CERN are carrying out experiments with subatomic pa use quantum mechanics to explain their properties.

A key concept underpinning quantum mechanics is that, for a photor energy of a photon and f is the frequency of the photon.

Explain what is meant by this statement.

Deduce what you think might happen to f if E was increased, base

SKILL B16: UNDERSTANDING SIMPLE PRO

Part A: Specification Overview

The exam board expects students to be able to recall their knowledge of b GCSE Mathematics course and apply it to the context of physics.

In particular, students will be expected to understand the concepts of pro radioactive decay of nuclei in radioactive sources.

Part B: Theoretical Overview

The probability of an event is said to range from impossible to certain, or respectively.

The equation for determining the probability of a repeated **fair event** is

$$\text{probability of an event} = \left(\frac{\text{number of ways this particular ou}}{\text{total number of outc}} \right.$$

where N is the number of times the event is repeated.

Note:

The probability of an event lies in between 0 and 1 (0% probability to 10

The probability will only ever be 1 (100%) if the outcome of the event ca absolute certainty.

This can be visualised easily using a probability scale:

(Impossible)
0

An event can also be described as being spontaneous.

An event is **spontaneous** if:
- the existence of other outcomes does not affect the outcome
- the existence of external factors does not affect the outcome

An event can also be described as being random.

An event is **random** if:
- the outcome of an event cannot be predicted

Independent, mutually exclusive and dependent events

Independent Events
Two events are **independent** if the outcome of one event has no effect on

For example, if you flip a coin and then flip it again, the outcome of the fi outcome of the second flip; you will have the same chance getting a head getting a head on the first flip.

The probability of the outcome of an event X can be written as P(X).

The combined probability of **multiple independent events** occurring can

If X and Y are both **independent events** then the probability of event X an

$$P(X\ and\ Y) = P(X) \times P(Y)$$

Mutually Exclusive Events
Two events are **mutually exclusive** if it is **impossible** for them to both ha

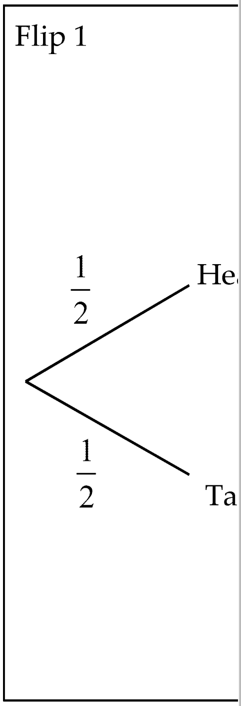
The combined probability of **multiple mutually exclusive events** occurri as follows:

If X and Y are **mutually exclusive** then the probability of event X **OR** eve

$$P(X\ or\ Y) = P(X) + P(Y)$$

A tree diagram can be used as a method to determine how to combine the and **mutually exclusive** outcomes, as discussed above.

Take our coin flip example.



The rules for tree diagrams is that you:

- add vertically across the branches (mutually exclusive outcomes)

  > **Note:** This is what we had before, the probability that X or Y will occur is P(X or Y) = P(X) + P(Y)

  e.g. P(Head, Flip 1 **or** Tail, Flip 1)

  = P(Head, Flip 1) **+** P(Tail, Flip 1) = $\frac{1}{2}+\frac{1}{2}=1$

- multiply horizontally across the branches (independent outcomes)

  > **Note:** This is what we had before, the probability that X and Y will occur is P(X and Y) = P(X) × P(Y)

  e.g. P(Head, Flip 1 and Head, Flip 2) = P(Head, Flip 1) × P(Head, Flip

For example:

Q1. What is the probability of flipping the coin once and the outcome b a second time and the outcome being tails?

A1: $P(H\ and\ T) = \left(\frac{1}{2} \times \frac{1}{2}\right) = \frac{1}{4}$

Q2. What is the probability of flipping the coin twice and getting oppo

A2: It is important to remember that there could be two cases for this as t what outcome (heads or tails) you get first and second, just that the o opposing outcomes.

Therefore:

- You flip first to get heads **and** then flip again to get tails

OR

- You flip first to get tails **and** then flip again to get heads

So you could flip either a head or a tail first and get a tail and a head resp options would satisfy the condition stated in the question

$$P(H\ and\ T)\ OR\ P(T\ and\ H) = \left(P(H) \times P(T)\right) + \left(P(T\right.$$

$$P(H\ and\ T)\ OR\ P(T\ and\ H) = \left(\frac{1}{2} \times \frac{1}{2}\right) + \left(\frac{1}{2} \times \frac{1}{2}\right) =$$

Dependent Events

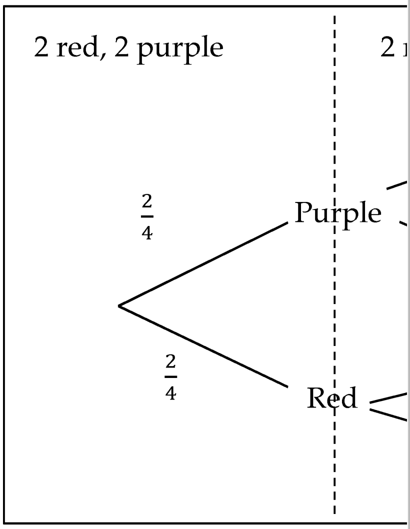
If an event is **dependent** then it means that the outcome of one event is af of another.

For example:

Let's say you had 4 sweets in a bag, 2 red and 2 purple. If you picked one the colour of the second sweet you pick will be dependent on or affected b

This is because before picking any sweets you had 2 red and 2 purple. H sweet out of the bag, depending on whether it was red or purple you will red and 1 purple left respectively. The selection you had when picking th different from the selection you have when picking the second sweet. Th pick second will therefore depend on what colour of sweet you choose fir

It is a lot easier to visualise this with a tree diagram. The same rules apply for tree diagrams of dependent outcomes. The only difference will be that the selection of your second outcome will be different to your first.



Part C: Worked Example

1. **If you flip a coin to get a head and then flip the coin again, what is t get another head?**

2. **There are 2 blue marbles and 3 green marbles in a bag.**

   Determine the probability of a blue marble being picked and then a

   The blue marble is not placed back in the bag after it is picked out.

3. **A Year 12 physics student used a set of dice to mimic the radioactiv used 168 square dice with six faces to represent the decay process.**

   She rolls the dice and removes any dice that land with the number 5 the remaining dice again and repeats this process a number of time

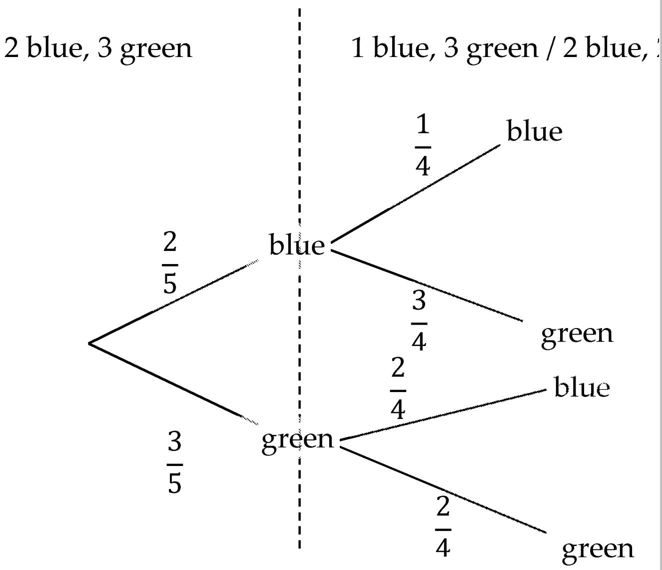
   a) **State what the remaining dice and throws represent in referenc decay process.**
   b) **Explain why this experiment is a useful model for representing radioactive decay.**
   c) **By indicating how many dice would remain after n throws, exp proves that the number of undecayed nuclei will decay expone decay process.**

Solution:

1. These are independent events; therefore, the outcome of the first flip d the second flip, and therefore the probability of flipping a head in the

   $$P(H)=\frac{1}{2}$$

2.



$$P(blue\ and\ green)=\frac{2}{5}\times\frac{3}{4}$$

$$P(blue\ and\ green)=\frac{6}{20}=\frac{3}{10}$$

3. a) Dice = undecayed nuclei
Throw = fixed time interval

b) • The student cannot predict when a dice will roll a 5 or which next, which mimics not being able to predict which nuclei wi decay next in radioactive decay.
• Each dice has the same chance of rolling a 5 as any of the oth radioactive decay as each undecayed nucleus has equal chan

c) On average, the number of dice removed (decayed) after the first t

Therefore, if 28 dice show a 5 on the first throw, the number of di (remaining undecayed).

The number of dice removed (decayed) after n throws will be ap

As the number of rolls (n) increases, the value of $(5/6)^n$ decreases the rate of decay slows over time, but there is never a point wher (reached zero).
This mirrors the behaviour of radioactive substances, where the r decreases exponentially over time.

Part D: Practice Questions

1. Explain what is meant by a random event.

2. The sketch below is of the probability scale; label the missing number

3. A child is holding a paper bag which contains 6 blue sweets and 3 gre sweet at a time from the bag.
a) What is the probability that the child's first sweet is blue?
b) The child eats the blue sweet. What is the probability that the sec bag is green?

4. An experiment investigating the radioactive decay process of nuclei v popcorn kernels.

A bag of unpopped kernels was placed in a microwave and allowed t
a) State what the unpopped kernels represent in the comparison to
b) Explain how the popcorn experiment mimics the radioactive dec
c) Sketch a graph of number of kernels against time, including on th unpopped kernels and a line representing kernels.

Skill B1: Units and conversion between units

1. B

2. a) kg
   b) K
   c) m
   d) mol

3. $188 \text{ kW} = 188 \times 10^3 \text{ W} = 188\,000 \text{ W}$

4. since $1 \text{ m} = 10^2 \text{ cm}$
   $10 \text{ cm} = 0.1 \text{ m}$ and $200 \text{ cm} = 2\text{m}$
   $V = \pi r^2 h$
   $V = \pi \times 0.1^2 \times 2$
   $V = 0.06283... = 0.063 \text{ m}^2$ (2 s.f.)

Skill B2: Use and calculate quantities in different forms

1. a) 2.57×10^6
   b) 2.36×10^{-3}
   c) 3.69×10^2
   d) 5.81×10^{-2}

2. a) 47,800,000
   b) 0.0012
   c) 76,300
   d) 0.0000000000000633

3. a) 8,300 kg
   b) $E_k = \frac{1}{2} m v^2$
   $E_k = \frac{1}{2}(8300) \times (11)^2$
   $E_k = 502150 \text{ J}$
   $E_k = 5.02 \times 10^5 \text{ J}$ (3 s.f.)

Skill B3: Estimation

1. $v \approx 30 \text{ ms}^{-1}$
   $d = v \times t$
   $d = 30 \times 10\,000$
   $d = 300\,000 \text{ m}$

2. $v \approx 300 \text{ ms}^{-1}$
   Plane 1:
   $d = v \times t$
   $d = 300 \times 10$ 8
   $d = 3\,240\,00$
   Plane 2:
   $d = v \times t$
   $d = 300 \times 14$ 4
   $d = 4\,320\,00$
   difference = 4

3. $M \approx 6 \times 10^{24}$
   $E_{grav} = -\frac{GM}{r}$
   $E_{grav} = -\frac{6.67}{}$
   $E_{grav} = -6.67$
   $E_{grav} = -7 \times$

Skill B4: Signifi

1. C

2. a) 30,500
   b) 568,000
   c) 0.00237

3. The calculate
   the measured
   Resistance sh

4. $a = \frac{F}{m}$
   $a = \frac{10\,500\,00}{2\,210\,00}$
   $a = 4.751131$
   $a = 4.75 \text{ ms}^{-2}$

Skill B5: Mean value

1. a) You would add up all the measured values for temperature and divide this by the number of measured values.
   b) $mean = \frac{T_1 + T_2 + T_3 + T_4 + T_5}{N}$

   $mean = \frac{77 + 76 + 75 + 78 + 77}{5}$

   $mean = 76.6 \text{ K}$

2. $mean = \frac{v_1 + v_2 + v_3 + v_4 + v_5}{N}$

   $mean = \frac{30 + 40 + 20 + 22 + 25}{5}$

   $mean = 27.4 \text{ mph}$

Skill B6: Use calculator to handle sin, cos and tan

1. Determine the solutions to the following equations:
   a) 9.77×10^{-3}
   b) 0.21
   c) 0.25

2. a) 16.7
   b) 73.1
   c) 56.1

3. $x = 10.3 \cos(1.3 \times 30)$

   $x = 2.7464... = 2.75 \text{ m (3 s.f.)}$

Skill B7: Use calculator to work with power functions

1. $a = b^2$

   $a = (3)^2$

   $a = 3 \times 3$

   $a = 9$

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

   $E = \frac{1}{2} \times \left(2.2 \times 10^4\right) \times (0.02)^2$

   $E = 4.4 \text{ J}$

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

   $P = \frac{(2.4)^2}{10.0}$

   $P = 0.576$

   $P = 0.58 \text{ W (}$

4. $v^2 = u^2 + 2as$

   $v^2 = (2.3)^2 +$

   $v^2 = 93.77$

   $v = \sqrt{93.77}$

   $v = 9.683... =$

Skill B8: Chang formula

1. D

2. $P = I^2 R$

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

   $\sqrt{\frac{P}{R}} = I$

   $I = \sqrt{\frac{P}{R}}$

3. a) $R = \frac{\rho L}{A}$

   $RA = \rho L$

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

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

   b) $m = \frac{\rho}{A}$

   $mA = \rho$

   $\rho = mA$

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

   $Ir^2 = \frac{P}{4\pi}$

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

   $r = \sqrt{\frac{P}{4\pi I}}$

Skill B9: Solving algebraic equations, including quadratics

1. $V = IR$

   $V = 0.2 \times 10$

   $V = 2\ \text{V}$

2. $I = Anev$

   $\frac{I}{Ane} = v$

   $v = \frac{I}{Ane}$

   $v = \frac{1.2}{(2.34 \times 10^{-7}) \times (8.5 \times 10^{28}) \times (1.6 \times 10^{-19})}$

   $v = 3.77 \times 10^{-4}\ \text{ms}^{-1}$

3. $F = m\left(\frac{v-u}{t}\right)$

   $\frac{F}{m} = \frac{v-u}{t}$

   $\left(\frac{F}{m}\right)t = v - u$

   $\left(\frac{F}{m}\right)t + u = v$

   $v = u + \left(\frac{F}{m}\right)t$

   $v = 0.44 + \left(\frac{1.5 \times 10^{6}}{7.1 \times 10^{7}}\right)360$

   $v = 8.0456... = 8.0\ \text{ms}^{-1}$ (2 s.f.)

4. $F = \frac{mv^2}{r}$

   $Fr = mv^2$

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

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

   $v = \sqrt{\frac{Fr}{m}}$

   $v = \sqrt{\frac{50 \times 13.}{670}}$

   $v = 1.0074...$

Skill B10: Abso

1. a) 0.05 A

   b) 0.1 ms^{-1}

   c) 4 J

2. $V_T = V_1 + V_2$

   $V_T = (1.2 \pm 0.$

   $V_T = (1.2 + 2.$

   $V_T = 231.2 \pm$

Skill B11: Percentage uncertainty (including percentage differe

1. $V_T = V_1 + V_2$

$$percentage\ uncertainty = \frac{0.2}{2.6} \times 100\%$$

$$percentage\ uncertainty = 7.7\%$$

2. $$percentage\ change = \frac{|new\ value - original\ value|}{original\ value} \times 100\%$$

$$percentage\ change = \frac{|3.9 - 4.6|}{4.6} \times 100\%$$

$$percentage\ change = \frac{0.7}{4.6} \times 100\%$$

$$percentage\ change = 15.217... = 15\%\ (2\ \text{s.f.})$$

3. a) $$percentage\ uncertainty = \frac{absolute\ uncertainty}{measured\ value} \times 100\%$$

$$percentage\ uncertainty = \frac{0.05}{5.2} \times 100\%$$

$$percentage\ uncertainty = 0.9615... = 0.96\%\ (2\ \text{s.f.})$$

b) $$percentage\ change = \frac{|new\ value - original\ value|}{original\ value} \times 100\%$$

$$percentage\ change = \frac{|6.4 - 5.2|}{5.2} \times 100\%$$

$$percentage\ change = 23.076... = 23\%\ (2\ \text{s.f.})$$

4. $P = (I \pm \Delta I) \times (V \pm \Delta V)$

$$P = (IV) \pm (\Delta I + \Delta V)$$

$$\%\ uncertainty\ I = \frac{\Delta I}{I} \times 100\% = \frac{0.05}{0.21} \times 100\% = 23.8\%$$

$$\%\ uncertainty\ V = \frac{\Delta V}{V} \times 100\% = \frac{0.1}{5.6} \times 100\% = 1.8\%$$

$$\%\ P = (23.8 + 1.8) = 25.6\%$$

$$\%\ P = \frac{\Delta P}{P} \times 100\%$$

$$\Delta P = \frac{\%P}{100\%} \times P$$

$$\Delta P = \frac{25.6}{100} \times (5.6 \times 0.21)$$

$$\Delta P = 0.301 = 0.3$$

$$P = 0.21 \times 5.6 = 1.176 = 1.2$$

$$P = 1.2 \pm 0.3\ W$$

The rounding of the final values is due to the number of significant fi
provided with.

5. $E_K = \frac{1}{2}(m \pm \Delta m) \times (v \pm \Delta v)^2$

$E_k = \frac{1}{2}mv^2 \pm \Delta m + (2\Delta v)$

$E_k = \frac{1}{2} \times 0.059 \times 57^2 = 95.8455 \text{ J}$

$\% \text{ uncertainty in } m = \frac{\Delta m}{m} \times 100\% = \frac{0.001}{0.059} \times 100\% = 1.7\%$

$\% \text{ uncertainty in } v = \frac{\Delta v}{v} \times 100\% = \frac{1}{57} \times 100\% = 1.8\%$

$\% \ E_k = (\%m + 2 \times \%v) = 1.7 + (2 \times 1.8) = 5.2\%$

$\% \ E_k = \frac{\Delta E_k}{E_k} \times 100\%$

$\Delta E_K = \frac{\% \ E_k}{100\%} \times E_k = \frac{5.2}{100} \times 95.8455 = 4.9875$

$E_k = 95.8455 \pm 4.9875 \text{ J}$

$E_k = 96 \pm 5.0 \text{ J (2 s.f.)}$

Skill B12: Angles

1. *a*: 41°
   b: 152°
   x: 28°
   y: 28°
   z: 152°

2. $x = 360 - (127 + 141) = 92°$

Skill B13: Converting between radians and degrees

1. B

2. a) 0.79 radians
   b) 2.2 radians
   c) 9.46 radians

3. a) 320°
   b) 69.9°
   c) 13°

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

$\sin C = \frac{1}{1.52}$

$\sin C = 0.657\ldots$

$C = 41.1395\ldots = 41.1° \text{ (3 s.f.)}$

Skill B14: Calculating areas and volumes

1. a) $V = Area \times h$

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

$V = \pi \times \left(\frac{d}{2}\right)^2 \times h$

$V = \pi \times \left(\frac{0.36}{2}\right)^2 \times 0.63$

$V = 0.06412... = 0.064 \text{ m}^3$ (2 s.f.)

b) $C = \pi \times d$

$C = \pi \times 0.36$

$C = 1.1 \text{ m}$

c) $Area\ of\ face = 0.20 \times 0.30$

$A = 0.06 \text{ m}^2$

OR $Area\ of\ face = 0.20 \times 0.60$

$A = 0.12 \text{ m}^2$

OR $Area\ of\ face = 0.30 \times 0.60$

$A = 0.18 \text{ m}^2$

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

$V = 0.20 \times 0.30 \times 0.60$

$V = 0.036 \text{ m}^3$

$V = 3.6 \times 10^{-2} \text{ m}^3$

2. $Area\ of\ right\text{-}angled\ triangle:$

$A = \frac{1}{2} \times l \times b$

$A = \frac{1}{2} \times 3.2 \times 4.1$

$A = 6.56 = 6.6 \text{ m}^2$ (2 s.f.)

$Area\ of\ isosceles\ triangle:$

$A = 2 \times (Area\ of\ right\text{-}angled\ triangle)$

$A = 2 \times \left(\frac{1}{2} \times l \times b\right)$

$A = 2 \times \left(\frac{1}{2} \times 1.1 \times 4.6\right)$

$A = 5.06 = 5.1 \text{ m}^2$ (2 s.f.)

3. $B = \rho V g$

$B = 1020 \times (0.300 \times 0.500 \times 0.600) \times 9.81$

$B = 900.558 = 901 \text{ N}$ (3 s.f.)

Skill B15: Mathematical symbols

1. A. True
   B. True
   C. False
   D. False

2. a) $P \propto F$
   b) $V_1 \ll V_2$
   c) $B > C$

3. The statement means that energy (E) is proportional to frequency (f

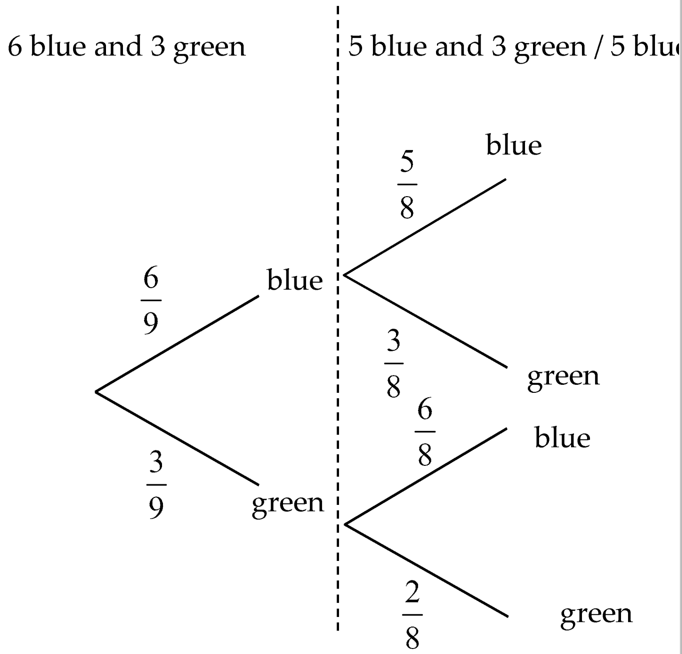
   This would therefore mean that if E was increased then f would in

Skill B16: Understanding simple probability

1. An event where:
   - the set of outcomes cannot be known
   - the order in which they occur cannot be known

2.

3. a) $\frac{6}{9}$
   b)

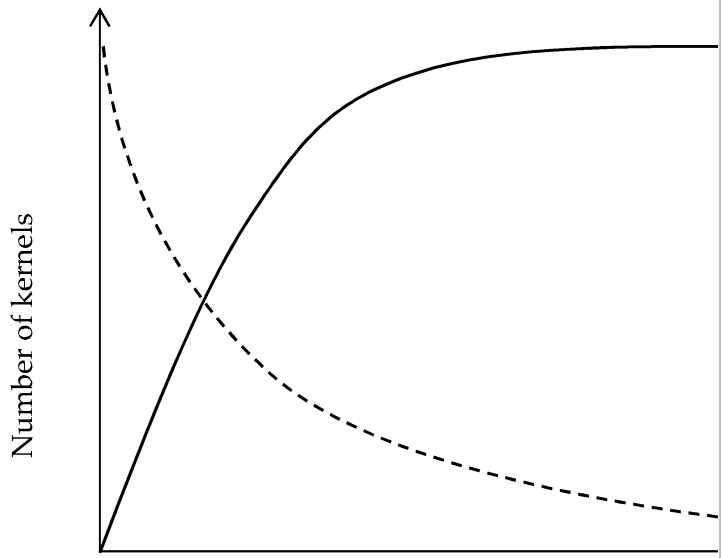


After the child has taken out the blue sweet and eaten it then there
(8 sweets)

P(blue and green) = P(blue) × P(green) = $\frac{6}{9} \times \frac{3}{8} = \frac{18}{72} = \frac{2}{8} = \frac{1}{4}$

4. a) Undecayed nuclei in a radioactive substance

b)
- When kernels begin to pop they represent a single decay. W (decay) cannot be predicted, and which kernel (nucleus) will predicted; therefore, it represents a *random event*, mimicking
- When and which kernel (nucleus) pops is not affected by the (nuclei), and every kernel (nucleus) has the same chance of p the event is a *spontaneous event*, mimicking the manner of dec
- Initially there is a large number of unpopped kernels and the passes the number of unpopped kernels decreases, as does th



c) Solid line indicates popped kernels and dashed line indicated un

Diagnostic Test 1

1. 4.58×10^6

2. 93 700

3. $151\times\frac{\pi}{180} = 2.6354\ldots = 2.64$ radians (3 s.f.)

4. $0.15\times\frac{180}{\pi} = 8.5943\ldots = 8.6°$ (2.s.f)

5. a) $A=\pi r^2$
   b) $A=\frac{1}{2}lb$

6. a) 402,400
   b) 0.2049

7. a) kg
   b) m
   c) A
   d) W

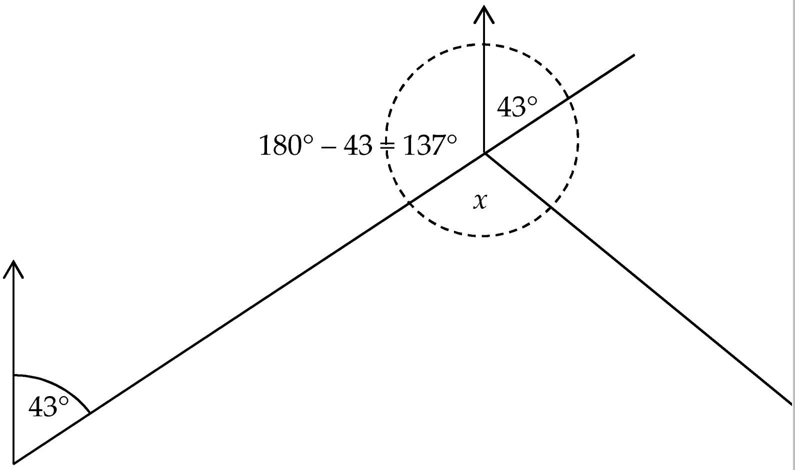
8. a) $x = \sin^{-1}(0.630) = 39.050\ldots = 39.1°$ (3 s.f.)
   b) $x = 0.8480\ldots = 0.85°$ (2.s.f)
   c) $x = -0.44522\ldots = -0.445°$ (3 s.f.)

9. a) 5.778×10^3 K
   b) 5780 K

10. a) A is proportional to the change in B
    b) C is equal to or less than D, and D is less than E
    c) F is much greater than G, and G is equal to or greater than H

11. a) $x = 33 + 90 = 180$
    $x = 57°$
    b) $x + 57 + 63 = 180$
    $x = 180 - (57 + 63)$
    $x = 60°$

12.



Therefore,

$$x + 137 + 159 = 360$$
$$x = 360 - (137 + 159) = 64°$$

13. $P = I^2R$
$P = 3.00^2 \times 14.0$
$P = 126$ W

14. a) 0.1 Hz
b) 0.01 m
c) $v = f\lambda$
$v = (2.3 \times 0.02)$
$v = 0.05 \text{ ms}^{-1}$
$$\frac{\Delta f}{f} = \frac{0.1}{2.3}$$
$$\frac{\Delta f}{f} = 0.09$$
$$\frac{\Delta \lambda}{\lambda} = \frac{0.01}{0.02}$$
$$\frac{\Delta \lambda}{\lambda} = 0.5$$
$$\frac{\Delta v}{v} = \frac{\Delta f}{f} + \frac{\Delta \lambda}{\lambda}$$
$$\frac{\Delta v}{v} = 0.09 + 0.5$$
$$\frac{\Delta v}{v} = 0.59$$
$\Delta v = 0.59 \times v$
$\Delta v = 0.59 \times 0.05$
$\Delta v = \pm 0.03 \text{ ms}^{-1}$
$\therefore v = 0.05 \ \pm 0.03 \text{ ms}^{-1}$

15. $percentage\ uncertainty = \dfrac{absolute\ uncertainty}{measured\ value} \times 100\%$

$percentage\ uncertainty = \dfrac{0.2}{56.9} \times 100\%$

$percentage\ uncertainty = 0.3514\ldots = 0.35\%$ (2.s.f)

16. $percentage\ change = \dfrac{|\,new\ value - orginal\ value\,|}{orginal\ value} \times 100\%$

$percentage\ change = \dfrac{|0.22 - 0.21|}{0.21} \times 100\%$

$percentage\ change = 4.761\ldots = 4.8\%$ (2.s.f)

17. $\theta = A\sin(xt)$

$\theta = 3.40 \times \sin(1.60 \times 1.70)$

$\theta = 3.40 \times \sin 2.72$

$\theta = 1.391\ldots$ radians

$1.391\ldots \times \frac{180}{\pi} = 79.717\ldots = 79.7^\circ$ (3 s.f.)

18. $v^2 = u^2 + 2as$

$v^2 = 5.8^2 + 2 \times 0.8 \times 10$

$v^2 = 49.64$

$v = \sqrt{49.64}$

$v = 7.0455\ldots = 7.0\ \text{ms}^{-1}$ (2 s.f.)

19. $mean = \dfrac{828\times10^3 + 827\times10^3 + 824\times10^3 + 827\times10^3 + 826\times10^3 + 824\times1}{6}$

$mean = 826\times10^3\ \text{km h}^{-1}$

20. Rolling dice can simulate radioactivity decay.
   - If you start off with x dice, then each dice can represent a single u and each throw represents an interval of time t.
   - If you choose the number, say 3, as the number that represents a probability for decay is $\frac{1}{6}$ for each dice (nucleus); therefore, with will decay and $\frac{5}{6}$ remain undecayed.
   - Therefore, the number of decays will be determined by change ar you cannot know which dice will decay, only their probability of
   - This is the same model of the radioactive decay of x undecayed n dice can be used to explain radioactive decay.

21. a) joules

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

$E_k = \frac{1}{2} \times (1.67 \times 10^{-27}) \times (2.30 \times 10^5)^2$

$E_k = 4.4171... \times 10^{-17}$ J = 4.42×10^{-17} J (3 s.f.)

c) Any of the following:

$E_k = 4.42 \times 10^{-5}$ pJ

$E_k = 4.42 \times 10^{-8}$ nJ

$E_k = 4.42 \times 10^{-11}$ μJ

$E_k = 4.42 \times 10^{-14}$ mJ

$E_k = 4.42 \times 10^{-15}$ cJ

$E_k = 4.42 \times 10^{-16}$ dJ

22. a) $F = kx$

1 cm = 10^{-2} m

$F = (3 \times 10^4) \times (20 \times 10^{-2})$

$F = 6000$ N

b) $F = 6$ kN

23.

a) $m \approx 6 \times 10^{24}$ kg and $r \approx 150\,000\,000\,000$ m

$E_{\text{grav}} = -\frac{GMm}{r}$

$E_{\text{grav}} = -\frac{6.67 \times 10^{-11} \times 1.99 \times 10^{30} \times 6 \times 10^{24}}{150\,000\,000\,000}$

$E_{\text{grav}} = -5.30932 \times 10^{33}$ J

$E_{\text{grav}} = -5.31 \times 10^{33}$

b) $1\,\text{kJ} = \times 10^3$ J

$E_{\text{grav}} = -5.31 \times 10^{30}$ kJ

c) $E_{\text{grav}} = -5.0 \times 10^{33}$ J

d) Mass of an adult ≈ 75 kg

Mass of a car ≈ 1200 kg

$F = -\frac{Gm_1m_2}{r^2}$

$F = -\frac{6.67 \times 10^{-11} \times 75 \times 1200}{1^2}$

So $F \approx 6 \times 10^{-6}$ N

Diagnostic Test 2

1. 2.369×10^8

2. 0.00631

3. 1.2 radians

4. 73.3°

5. a) $A = \pi r^2$
   $A = \pi \times (3)^2$
   $A = 28.27$
   $A = 28.3 \text{ cm}^2$
   b) $A = l \times b$
   $A = 7.2 \times 9.4$
   $A = 68 \text{ m}^2$
   c) $V = A \times h$
   $V = \pi r^2 \times h$
   $V = \pi \times 1.5^2 \times 5.1$
   $V = 36 \text{ m}^3$
   d) $V = A \times h$
   $V = l \times b \times w$
   $V = 3.6 \times 4.7 \times 1.1$
   $V = 19 \text{ m}^3$

6. a) 53,021.6
   b) 0.0365821
   c) 2.30000×10^{-7}

7. a) mol
   b) ohm (allow Ω)
   c) m^3
   d) s

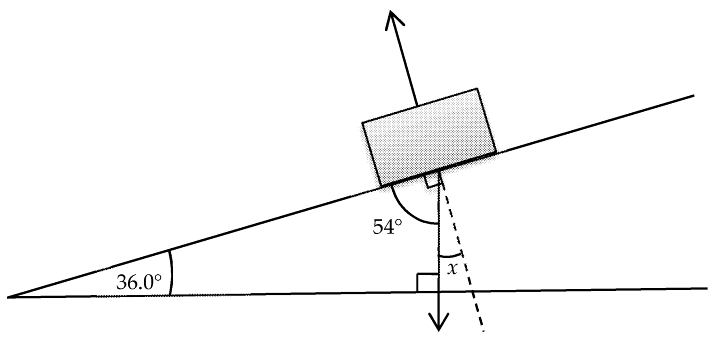
8. a) $x = \cos^{-1}(0.69)$
   $x = 46.369... = 46°$ (2 s.f.)
   b) $x = 0.9998...$
   c) $x = \tan^{-1}(0.47)$
   $x = 25.173... = 25°$ (2.s.f)

9. a) 1.382×10^{10} years
   b) 1,380,000,000,000,000 years

10. a) A is much less than B and B is much less than the change in C
    b) C is less or equal to the change in D divided by the change in E
    c) F is proportional to x if x is greater than or equal to 3

11. x: 33°
    a: 33°
    b: 35°
    h: 100°

12.



a) $x = 36°$

b) $a = g \sin x$

$a = 9.81 \times \sin 36$

$a = 5.7661... = 5.77 \text{ ms}^{-2}$ (3 s.f.)

13. $s = ut + \frac{1}{2}at^2$

$s = (2.5 \times 150) + \frac{1}{2} \times 0.2 \times (150)^2$

$s = 2625$ m = 2630 m (3 s.f.)

14. a) 1 Hz

b) 0.1 m

c) $v = f\lambda$

$v = (150 \times 3.3)$

$v = 495\text{W}$

$\frac{\Delta f}{f} = \frac{1}{150}$

$\frac{\Delta f}{f} = 0.00666...$

$\frac{\Delta \lambda}{\lambda} = \frac{0.1}{3.3}$

$\frac{\Delta \lambda}{\lambda} = 0.0303...$

$\frac{\Delta v}{v} = \frac{\Delta f}{f} + \frac{\Delta \lambda}{\lambda}$

$\frac{\Delta v}{v} = 0.00666... + 0.0303...$

$\frac{\Delta v}{v} = 0.0369...$

$\Delta v = 495 \times 0.0369...$

$\Delta v = \pm 18.3$

15. $percentage\ uncertainty = \frac{absolute\ uncertainty}{measured\ value} \times 100\%$

$percentage\ uncertainty = \frac{0.005}{0.02} \times 100\%$

$percentage\ uncertainty = 25\%$

16. $percentage\ change = \frac{|new\ value - original\ value|}{original\ value} \times 100\%$

$percentage\ change = \frac{|35-30|}{30} \times 100\%$

$percentage\ change = 16.66... = 17\%$ (2 s.f.)

17. $V = \frac{(9.11\times10^{-31})\times(2.98\times10^{6})^2}{2\times(1.6\times10^{-19})}$

$V = 25.2813... = 25$ V (2 s.f.)

18. $mean = \frac{98.6+98.9+98.7+98.9+98.2+98.5}{6}$

$mean = 98.633... = 98.6\%$ (3 s.f.)

19. Mass of a car ≈ 1200 kg
Speed of a car on a motorway ≈ 30 m/s

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

$E_k = \frac{1}{2} \times 1200 \times 30^2$

$E_k \approx 5.4 \times 10^5$

20. a) V is proportional to I when T is constant.
b) $V = IR$
$V = (2.3)\times(100)$
$V = 230$ V

21. The student cannot predict when a dice will roll a 4 or which dice out mimics not being able to predict which nuclei will decay or which nu radioactive decay.

Each dice has the same chance of rolling a 4 as any of the other 139 di decay as each undecayed nucleus has equal chance of decaying.

22. a) $F = -\frac{GMm}{r^2}$

$F = -\frac{(6.67\times10^{-11})\times(6\times10^{24})\times(7.35\times10^{22})}{(400\,000\,000)^2}$

$F = -1.83841875\times10^{20}$ N

$F = -1.84\times10^{20}$ N (3 s.f.)

b) $F = -1.84\times10^{17}$ kN

c) $F = -1.8\times10^{20}$ N