Question Writing
- Getting Started -

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Getting started – motivation

There's always some *reason* for writing a new question. For example:

- Is there a problem you are trying to solve?
- Is there a particular teaching challenge you are trying to overcome?
- Is there a gap you are trying to fill?
- Is there a difficulty level you are addressing?

The reason affects the form the new question takes.

Getting started – example problem

Problem: "Sixth form students struggle to apply trigonometry in physics."

Analysis:
- The students can do trigonometry in maths.
- The problem is the transition between subjects.

Context: Maths for new sixth form science students workshop
$\longrightarrow$ want to recap GCSE knowledge

Solution: Question structure –
maths summary, maths practice, physics application

Getting started – example problem

“Sixth form students struggle to apply trigonometry in physics.”

Rule summary

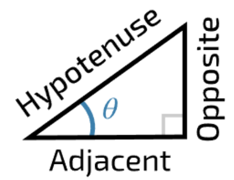

Figure 1: Side labelling for trigonometry

Trigonometry is a useful tool for calculating quantities in science in situations where right-angled triangles can be drawn.

This question is about $\sin\theta$. For a right-angled triangle,

$$\sin\theta = \frac{\text{Opposite}}{\text{Hypotenuse}}$$

Maths practice

Part A Find side length x

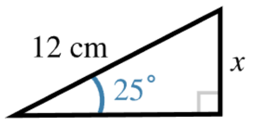

Figure 2: A right-angled triangle with a side of length x.

Use trigono

Part B Find side length L

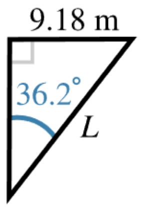

Figure 3: A right-angled triangle with a side of length L.

Find the side length L.

Physics application

Part C Find the component $W_\parallel$

A car is stationary on a hill which has a slope of $5.0\,^\circ$ to the horizontal. The weight of the car, $12\,000\,\text{N}$, acts vertically downwards.

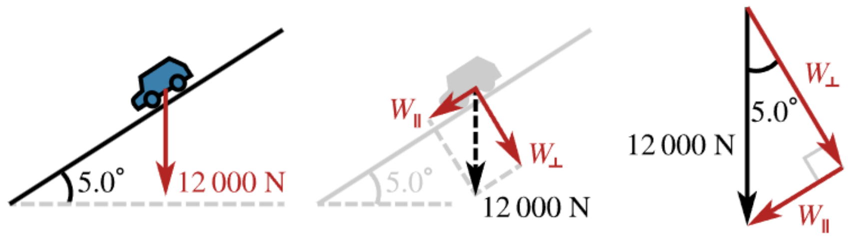

Figure 4: Illustrating how the weight of a car on a slope can be split into components parallel to the slope $W_\parallel$ and perpendicular to the slope $W_\perp$.

The weight of the car can be thought of as having a component parallel to the slope, $W_\parallel$, plus a component perpendicular to (at right-angles to) the slope, $W_\perp$. Use trigonometry to find the size of the component parallel to the slope, $W_\parallel$.

Getting started – example teaching challenge

Scenario: "1 hour to teach the basics of complex numbers to A level students at a summer school."

Challenges:

- No prior knowledge of the topic.
- The information is technical, and abstract.
- Short amount of time.

Solution: Each question teaches one thing -

- ➢ summarise rule at start
- ➢ several parts for practice
- ➢ avoid any subtle points

Getting started – example teaching challenge

"Summer school: only 1 hour to teach the basics of complex numbers."

Summary of rule

During addition, the real and imaginary parts of complex numbers are summed separately. Similarly, during subtraction the real and imaginary parts of complex numbers are subtracted separately. If $z_1 = u + v\mathrm{i}$ and $z_2 = p + q\mathrm{i}$,

$$z_1 + z_2 = (u+p) + (v+q)\mathrm{i}$$
$$z_1 - z_2 = (u-p) + (v-q)\mathrm{i}$$

Practise using the rule

Part A $z_1 = 2 + 3\mathrm{i}$ **and** $z_2 = 4 + 5\mathrm{i}$

$z_1 = 2 + 3\mathrm{i}$ and $z_2 = 4 + 5\mathrm{i}$. What is the value of $z_1 + z_2$?

Part B $z_1 = -3 + 4\mathrm{i}$ **and** $z_2 = 7 - 6\mathrm{i}$

Part C $z_1 = 2 - 7\mathrm{i}$ **and** $z_2 = -6\mathrm{i}$

Part D $z_1 = 3 + 8\mathrm{i}$ **and** $z_2 = 1 + \mathrm{i}$

Part E $z_1 = -4 + 2\mathrm{i}$ **and** $z_2 = 1 - 3\mathrm{i}$

Part F $z_1 = 4$ **and** $z_2 = -12\mathrm{i}$

Getting started – example of filling a gap

Gap: "We need more questions on motion with constant acceleration in 2D to use in maths."

Analysis: Just after "more" questions

Solution: Questions "like those in the textbook" -

- no need to summarise any theory
- practise the same ideas as existing questions, just with new contexts
- useful if there is a broader "learning point" to take away from doing a question

Getting started – example of filling a gap

"We need more questions on motion with constant acceleration in 2D."

New context

Figure 1 shows a particle of mass $m\,\mathrm{kg}$ moving on a smooth plane inclined at an angle $\theta°$ to the horizontal. A pair of axes is marked on the plane. The y-axis is aligned with the line of greatest slope of the plane. The x-axis is perpendicular to the y-axis and is horizontal.

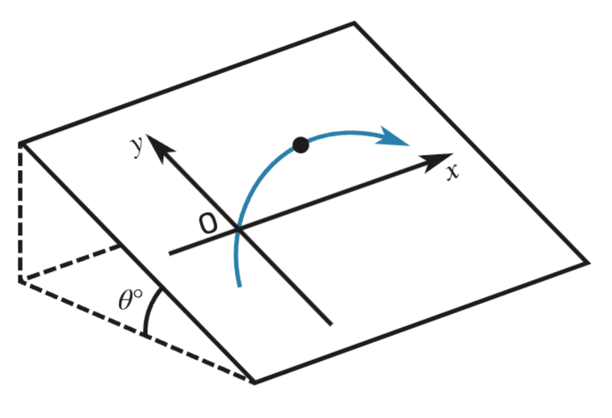

Figure 1: A particle moving on an inclined plane.

By resolving forces, the resultant force on the particle is found to be $\boldsymbol{F}_{\text{res}} = \begin{pmatrix} 0 \\ -mg\sin(\theta) \end{pmatrix}$.

Learning point: just like projectile motion, but with $g\sin\theta$ instead of g

Standard practice

Part A **Expression for $\boldsymbol{v}$**

Find an expression for the velocity of the particle $\boldsymbol{v}\,\mathrm{m\,s^{-1}}$ as a function of time t s and θ, given that the velocity of the particle is exactly $2\boldsymbol{i} + 2\boldsymbol{j}\,\mathrm{m\,s^{-1}}$ when $t = 0$. Give your answer in the form $a\boldsymbol{i} + b\boldsymbol{j}$, where $\boldsymbol{i}$ and $\boldsymbol{j}$ are unit vectors in the x and y directions.

Type your formula here ?

The following symbols may be useful: `g, i, j, t, theta`

or click here to drag and drop your answer

Check my answer

Hint 1 | Hint 2

Part B **Angle of the plane**

Part C **Speed after $1.0\,\mathrm{s}$**

Getting started – example of filling a gap

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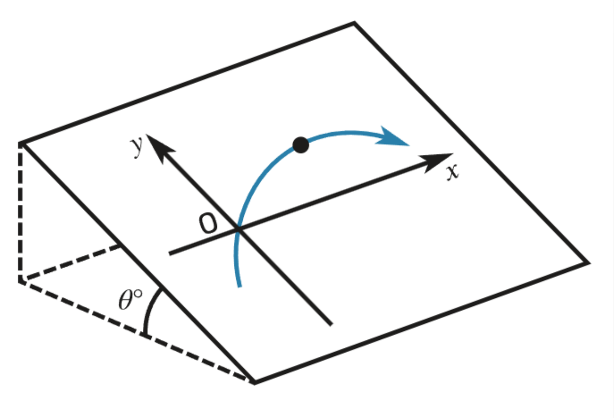

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Learning points are often not intentional!

↓

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Getting started – examples of writing for a difficulty level

Issue: "Can we have some more challenging questions?"

My response: Yes!

Solutions: Lots of possibilities -

- very hard version of a standard question to test topic mastery ("kitchen sink")
- extension of an idea in a novel way
- extension to next level of education

Getting started – examples of writing for a difficulty level

Issue: "Can we have some more challenging questions?"

My response: Yes!

(I like our STEM SMART students!)

Solutions: Lots of possibilities -

- very hard version of a standard question to test topic mastery ("kitchen sink")
- extension of an idea in a novel way
- extension to next level of education

Getting started – example of mastery question

“If you can do this, you can do anything in this topic.”

Standard question (from old A level paper)

Solve the equation $2^{4x-1} = 3^{5-2x}$

Maths challenge question - “kitchen sink” approach

Find the two solutions to the following horrible "log jam"!

$$x \log_\pi 3 = \frac{1}{4} \log_\pi 81 \times \log_3 \left(5 \times 3^{x \log_3 2} + 7e^{x \ln 3} - 35\right) - \log_\pi 2^x$$

Getting started – example of novel extension of an idea

"Can you extend what you know to do this as well?"

Log plots – what happens if you made a 3D plot?

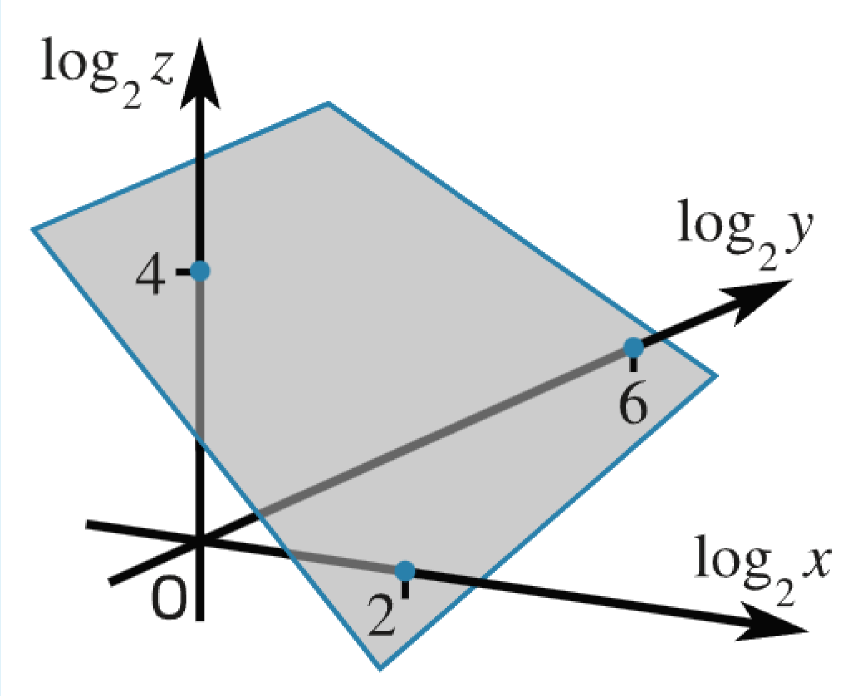
Part A **Power law relationship**

In an experiment the variable z depends on the variables x and y according to the relationship

$$z = ax^b y^c$$

where a, b and c are constants.

Figure 1 below shows a plot of $\log_2 z$ against $\log_2 x$ and $\log_2 y$. Use this plot to find the values of a, b and c.



Getting started – example of next level of education

"Gives a useful / inspiring glimpse of the future."

A level application

Part A **Maximum height of a projectile**

A particle is fired upwards into the air with an initial speed w and moves subsequently under the influence of gravity with an acceleration g downwards, such that its height h at time t is given by $h = wt - \frac{1}{2}gt^2$, where w and g are constants. Find an expression for its maximum height above its initial position.

University application

Part B **Potential energy of two molecules**

The potential energy of two molecules separated by a distance r is given by

$$U = U_0\left(\left(\frac{a}{r}\right)^{12} - 2\left(\frac{a}{r}\right)^{6}\right)$$

where U_0 and a are positive constants. The equilibrium separation of the two molecules occurs when the potential energy is a minimum.

Find an expression for the equilibrium separation of the molecules.

Question by Dr. Julia Riley

Getting started – diagrams

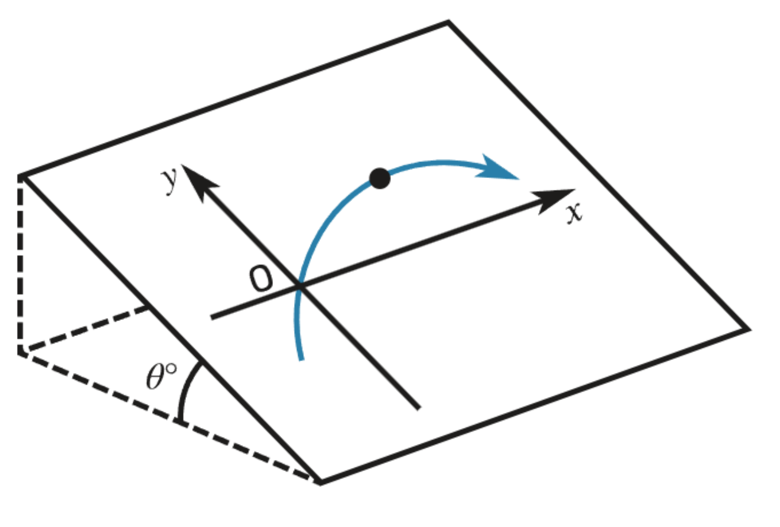
"Draw a diagram!"

3 reasons diagrams are important:

1. Diagrams help students understand the scenario.
   - Really helpful for novel contexts or contexts with lots of geometry.

2. Diagrams help students "get inside your head" as the writer.

Figure 1 shows a particle of mass $m\,\mathrm{kg}$ moving on a smooth plane inclined at an angle θ° to the horizontal. A pair of axes is marked on the plane. The y-axis is aligned with the line of greatest slope of the plane. The x-axis is perpendicular to the y-axis and is horizontal.



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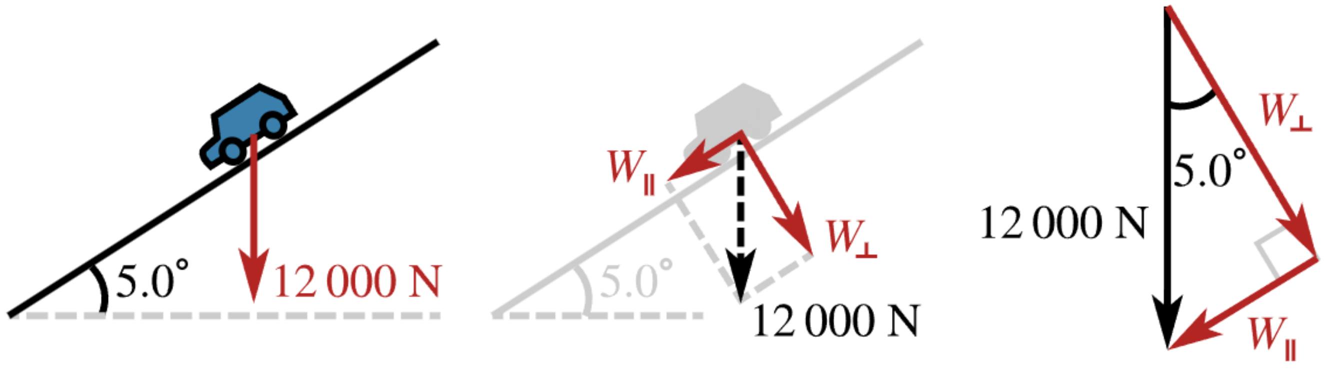
Getting started – diagrams

"Draw a diagram!"

3 reasons diagrams are important:

3. Diagrams can be used within a question as a teaching tool.

   - A sequence of diagrams can be helpful.



Practical point: it can take several iterations to get a diagram right. (True for questions too!)

Getting started – diagrams: examples for KS3

"Draw a diagram!"

At KS3 **illustrations** in questions serve a number of purposes:

Decorative

Useful as it makes the material more interesting and provides a real-world connection.

Explanatory

Shows students what the "chest expander" in the question is.

Illustrates a physical point

Getting started – diagrams: examples for KS3

"Draw a diagram!"

At KS3 students are starting to learn a physics way of looking at the real world. This involves learning to draw **diagrams**:

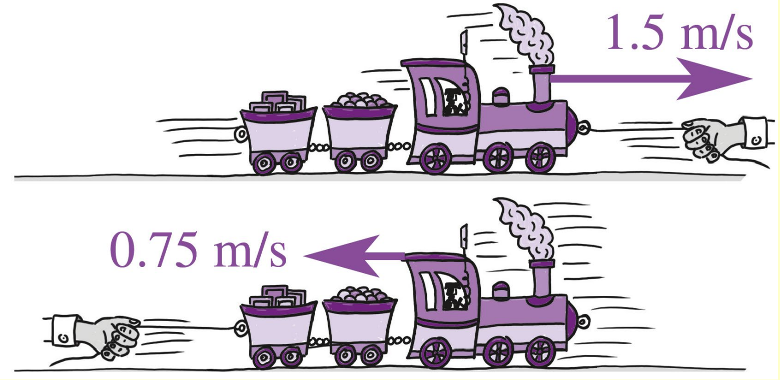
- We start with the real world. What physical quantities and properties are we interested in?
- We learn to isolate what is important for physics, and what is inessential.
- We end up drawing diagrams which ONLY include the essential information needed for the physics we are thinking about.

More abstract

Getting started – diagrams: examples for KS3

"Draw a diagram!"

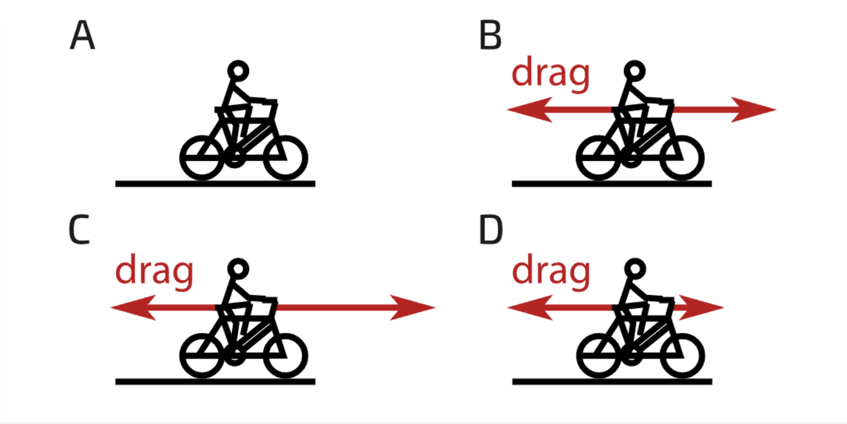
In KS3 questions we use diagrams which reflect different stages of this process.



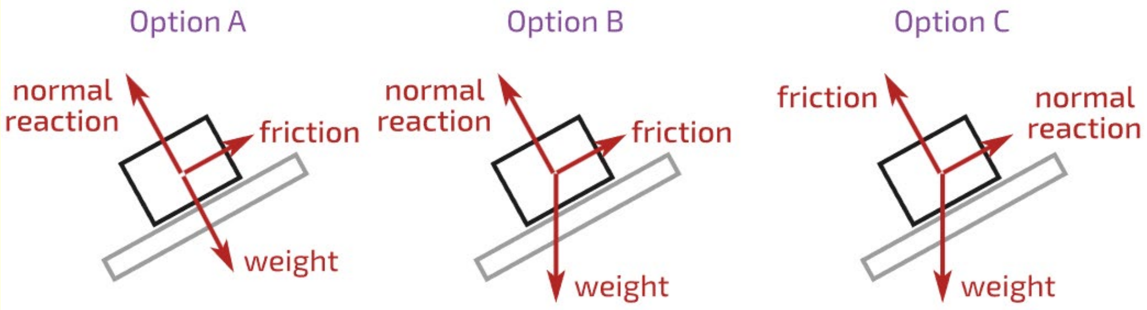
Connection to real world

More abstract

(a) Choose the diagram which shows the driving and drag forces on a cyclist when they are speeding up.



Useful at a higher level



Getting started – diagrams: examples for KS3

"Draw a diagram!"

Before you know it, your students will be drawing perfect abstract diagrams - like this beauty:

"Wow!"
Prof. S. Awww

"What a corker!"
Mr. E. Scientist

"Stunning!"
Dr. Irma Critic