Problem solving questions for A Level Physics

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Writing problem solving questions

- **Audience**: A Level students who enjoy Physics & Maths and want to apply their knowledge from the course to challenging problems

- **Aims**:
    - To write problems which test a student's problem-solving skills
    - To reinforce the connection between Physics and Maths
    - To improve fluency in applying and manipulating equations
    - To consolidate A Level concepts and using them in unfamiliar situations

What makes a good question?

- Something a bit different:
  - Unusual setups / unfamiliar applications
- Familiar concepts:
  - Should be topics covered on the specification – no extra reading
- Multiple-step reasoning (may be more than one valid method):
  - ’first use this equation, then this assumption, then another equation’
- Avoids unnecessary complexity:
  - E.g. awkward unit conversions (lbf/in^2 -> MPa)
- Provides enough information to clearly define the setup, but also concise
- Neat answer (not always necessary)

Step 1: Come up with an idea

- Often the most difficult part!
- Choose a pair of topics/concepts, and think of ways to combine them
- Choose an interesting set-up/geometry
- Has to be physically correct, but doesn't have to be practical!
- Look at past papers/Olympiad papers
- Random inspiration (write down the idea for later)

Step 2: Do the algebra

- The question may fail:
  - Not the right level
  - Equations too complicated
  - Too many assumptions
  - Back to Step 1!

- Decide whether the answer should be numeric or symbolic

Step 3: Write it up

- Decide whether you will give the diagram in the question, or expect the student to draw their own based on the information given
- State assumptions, variables, constants
- Check if values given are sensible
- Length:
  - I usually aim for ½ A4 page of algebra for a typical challenge question
- Number of parts?
  - Typically 1–3 parts; too much structure will guide the student along a particular method

Step 4: Review

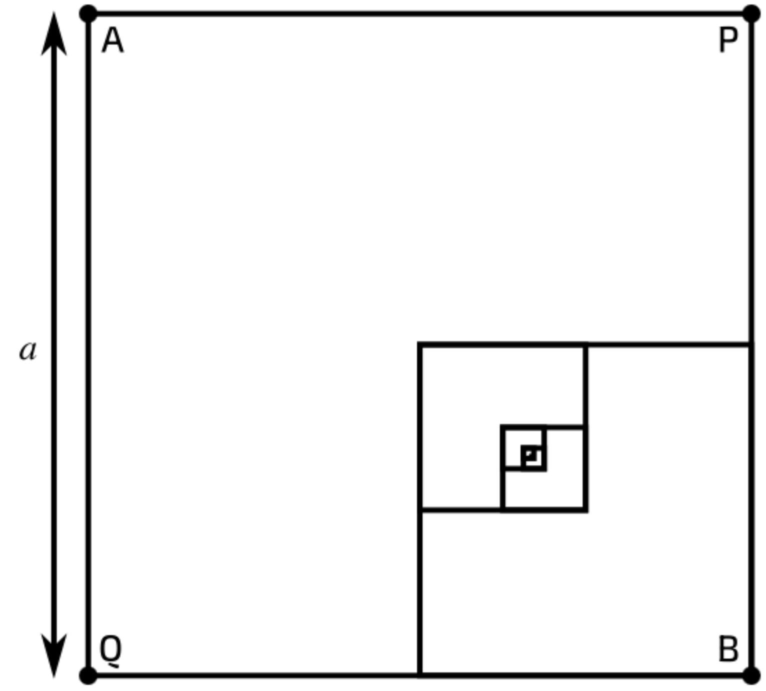
- Give to a student or another teacher (or AI?)
- Question might need rewording / diagram might need changes etc.
- Useful to see another person’s method
- Should be challenging yet solvable and fun!

Example: Resistor Recursion (A Level C2)

The pattern in **Figure 1** shows a square of side length a.

From the midpoints of two adjacent sides, straight lines of equal length are drawn to divide the square into the ratio $3:1$ by area. The process is repeated infinitely within the smaller piece of the square each time.

This pattern is recreated using a thin wire, with uniform resistance per unit length k. Although it is not physically possible to perfectly recreate this infinitely repeating pattern, we are interested in the limit of large numbers of repetitions.



Example: Moving Fringes (A Level C3)

A double slit aperture is printed on a thin, transparent and flexible film. The film is stretched from the sides with a time-varying force so that the slit separation d is given as a function of time t as

$$d(t) = d_0 \left(1 + \frac{2}{7} \sin \omega t\right),$$

where d_0 and ω are constants.

Coherent monochromatic light of wavelength λ passing normally through the aperture produces a diffraction pattern on a screen placed a distance L away from it. The fringes can be assumed to be evenly spaced on the screen.

Find an expression for the maximum speed of the 3rd order maxima as viewed on the screen.

Example: Toroidal Motion (A Level C3)

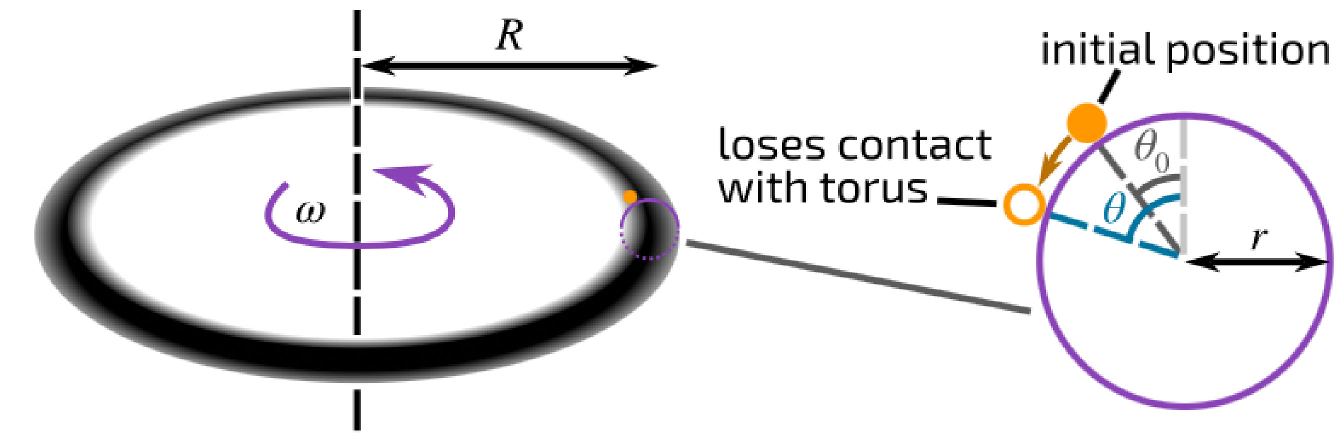


Figure 1: A torus of outer radius R, rotating at angular velocity ω. A close-up of the cross-section which contains the mass. [*A torus is the shape of a doughnut. Specifically, it is the surface which is created when a circle is revolved completely about an axis in the same plane. In this question, this axis is far outside of the circle.*]

A smooth rigid torus is rotating at angular velocity ω about a vertical axis through its centre. It has two radii, r and R as shown in Figure 1, and $r \ll R$.

A point mass lies on the outer surface of the torus, and is co-rotating with it in a horizontal plane (it is moving in the **toroidal direction**). It is given a very small impulse, perpendicular to its velocity, and begins to slide downwards along a cross-sectional circle of radius r (it starts moving in the **poloidal direction**). The acceleration due to gravity g is downwards.