

Problem Set 2: Tackling physics problems

Issued on 25th June 2026, solutions webinar hosted on 1st July 2026 - written by Dr Justin Palfreyman

1. Drag dimensions

The drag force F on a sphere is related to the radius of the sphere, r , the velocity of the sphere, v , and the coefficient of viscosity of the fluid the drop is falling through, η , by the formula

$$F = k r^x \eta^y v^z$$

where k is a dimensionless constant, and x , y , and z are integers.

By considering the units of the equation, work out the values of x , y , and z .

Note: The coefficient of viscosity has units of $[\text{kg m}^{-1}\text{s}^{-1}]$.

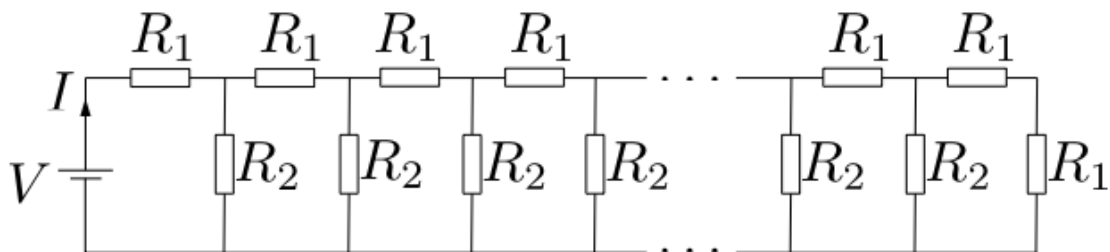
2. Radioactive decay

A radioactive sample contains two different isotopes, A and B. A has a half-life of 3 days, and B has a half-life of 6 days. Initially in the sample there are twice as many atoms of A as of B.

At what time will the ratio of the number of atoms of A to B be reversed?

3. Infinite resistors - Part II

In the circuit diagram below, let $R_1 = R_2 = 10\Omega$ and $V = 10\text{V}$.¹



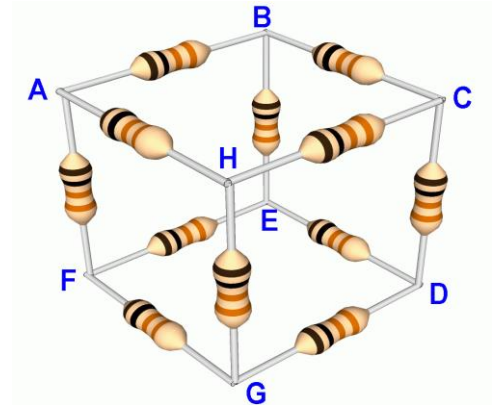
Calculate the value of I .

¹ https://i-want-to-study-engineering.org/q/infinite_loops_circuit_2

4. Resistor networks Part II

A cube of resistors, ABCDEFGH, is made with 12 identical resistors of resistance R.

Determine all the possible values of resistance (in terms of R) that could be produced by connecting an ohmmeter to any pair of vertices (e.g. A-B, A-C, A-D etc...)



5. Maximum range - Parts II

Show that, if the cannon is at the top of a hill, with an incline of ϕ , then the range equation can now be written as:

$$R = \frac{u^2}{g} [\sin 2\theta + \tan \phi \{1 + \cos 2\theta\}].$$

6. Maximum range - Part III

Determine the relationship between θ and ϕ that maximizes the range.

7. Motion-time graphs - Part II

A football is dropped from the leaning tower of Pisa, accelerating to close to its terminal velocity before hitting the ground.

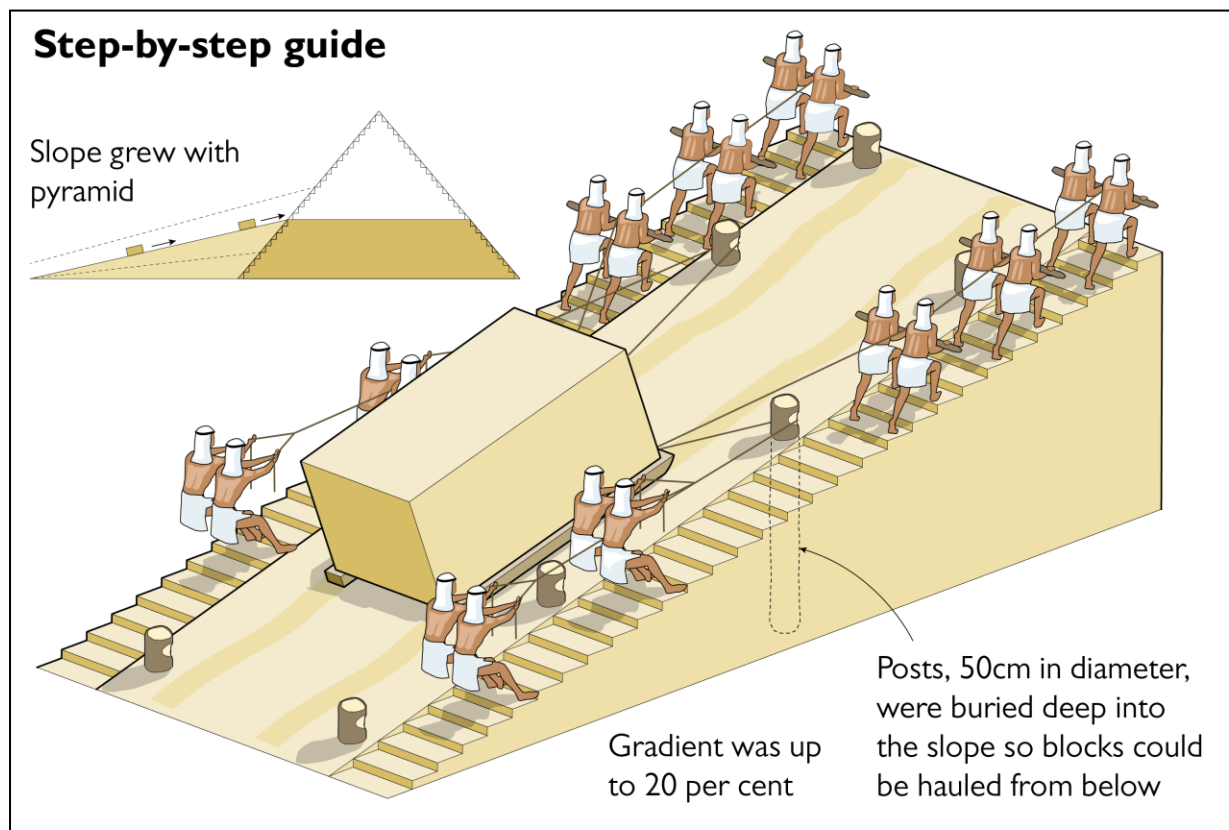
It rebounds inelastically, reaching a third of its original height – for this part of its motion we can neglect the effect of air resistance.

Sketch the motion graphs (displacement-, velocity- and acceleration-time) from the moment of release until it hits the ground for a second time.

Building The Great Pyramid of Giza – Part II

Estimating the width of the slope as 7 m by using the 50 cm diameter posts for scale, the volume of the ramp would have been around $1.81 \times 10^5 \text{ m}^3$ or ~6.8% the volume of the pyramid. Scholars suspect the ramp would have been closer to double this width however.

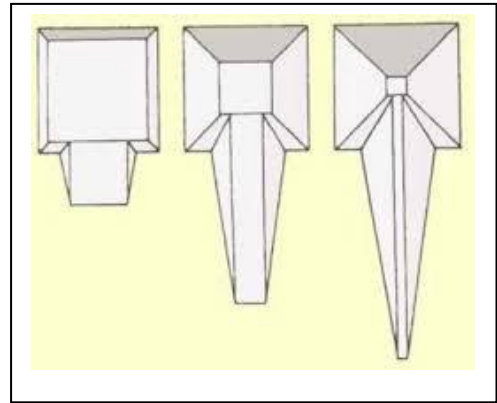
If the ramp were made of sand (or other granular materials), the sides would not have been vertical. The angle of repose (angle of slope from the horizontal) is usually $30 - 45^\circ$ for such materials.



8. Realistic Sand Ramp

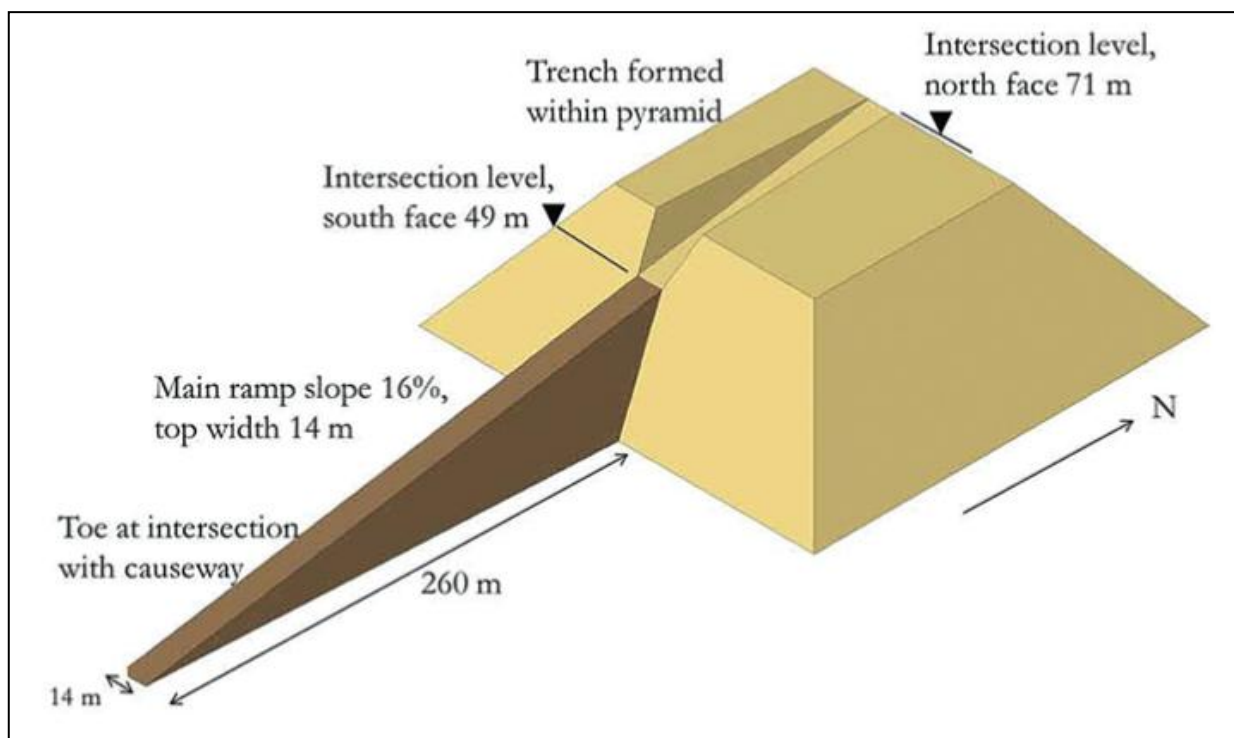
To estimate the size of a sand ramp with sloped sides, the maths will quickly become quite ugly, so let's do what physicists do – start with a simple model, then add layers of complexity if we fancy the challenge.

- a) Let's draw a ramp 14 m wide, with an 18° slope that meets the pyramid when it's also 14 m wide. Assume the sides of the ramp made a 45° angle with the horizontal as almost shown in the depiction on the right.



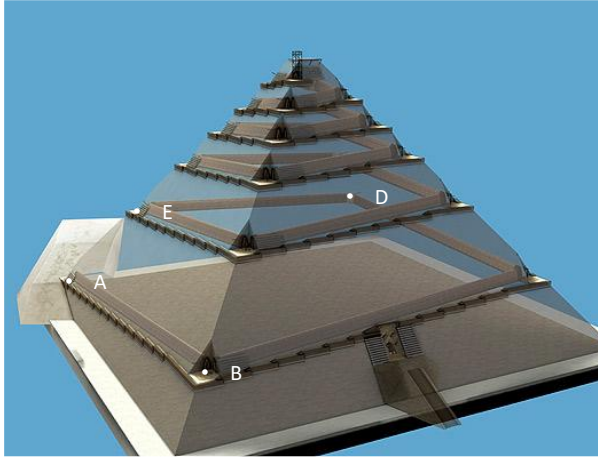
Now ignore the pyramid and just calculate the volume of such a ramp.

- b) If we put the pyramid back in place, it would intersect a portion of this ramp, so if we subtract that intersection it would give us a better estimate for the volume of the ramp.
- c) We could save even more volume if instead of meeting the pyramid on its near side, it actually stopped when it got to where the far side was 14 m. The picture below shows this idea, but meeting it lower down without the side slopes.



A giant ramp of this type seems quite unlikely and there is little evidence of it² actually existing. However, there has been evidence that supports the idea of ramps spiralling around the pyramid with the pyramid itself providing the majority of the necessary support structure.

9. Spiral Ramp



The figure depicts such a structure with an incline of only 6.4° , which will vastly reduce the force the workers needed to apply. There is also evidence of the workers lubricating the ramps to further reduce the coefficient of friction to around 0.25.

However, the largest granite blocks in the Kings Chamber weighed 50-80 tonnes!

Assume that the ramp at point A starts at a corner of the pyramid, at its base. Calculate the distance between the following points as represented in the figure above

- a. A and B
- b. A and E – following the spiral path.

Hint: draw a large and well-annotated 2D diagram to start with. Once you've found the first distance, look for symmetries to reduce the number of steps.

10. Total length

Find, in **two** different ways, the total distance from A to the apex up the inclined ramp.

Hint: assume the spiraling never stops.

² 6,000 years is probably long enough for the wind to blow the sand away though.