

МАТЕМАТИКА

Q: Imagine a ladder leaning against a vertical wall with its feet on the ground. The middle rung of the ladder has been painted a different colour on the side, so that we can see it when we look at the ladder from the side on. What shape does that middle rung trace out as the ladder falls to the floor?

Answer: This question tests whether you can do what mathematicians do, which is to abstract away all the unimportant information and use mathematics to represent what's going on. I'd initially ask the candidate what shape they think will be formed, and then ask them how they can test this hypothesis. They might initially try sketching the ladder at different stages – this is fine, but ultimately what we want is something that we can generalise and that is accurate (you can't be sure that your drawing is that accurate, particularly when you're making a sketch on a whiteboard and don't have a ruler). So eventually they will fall back on maths, and try to model the situation using equations. If they get stuck we would ask them what shape the ladder makes with the wall and floor, and they'll eventually spot that at each stage the ladder is forming a right-angled triangle. Some might then immediately leap to Pythagoras' Theorem and use that to find the answer (which is that it forms a quarter circle centred on the point where the floor meets the wall).

This is a fun question because the answer is typically the opposite of what they expect because they think about the shape the ladder makes when it falls (which is a series of tangents to a curve centred away from the wall and the floor). A nice extension is what happens when we look at a point $1/3$ or $2/3$ up the ladder.

Some other questions:

What are the max and min values of $f(x)=x^2$ between $-\infty$ and $+\infty$?

A watch face shows 3:15. What is the angle between the hands?

A sequence exists such that $a_n = 1/n$. Where does this sequence converge?

Draw the graph of $f(x)=\ln(x)$.

What are the maximum and minimum values of $f(x)=x^2$ between -1 and 1 ?

ФИЗИКА:

1. A ball bearing is flying through space (vacuum and no overall gravitational field). It heads towards a doughnut, through its centre and out the other side. Draw graphs of 1) speed versus time and 2) acceleration versus time.
2. An ant starts at one vertex of a solid cube with side of unity length. Calculate the distance of the shortest route the ant can take to the furthest vertex from the starting point.
3. A telephone company has run a very long telephone cable all the way round the middle of the earth. Assuming the Earth to be a sphere, and without recourse to pen and paper, estimate how much additional cable would be required to raise the telephone cable to the top of the 10m tall telephone poles.
4. A thin hoop of diameter d is thrown on to an infinitely large chessboard with squares of side L . What is the chance of the hoop enclosing two colours?

5. An infinitely large floor is tiles with regular hexagonal tiles of side L . Different colours of tiles are used so that no two tiles of the same colour touch. A hoop of diameter d thrown onto the tiles. What is the chance of the hoop enclosing more than one colour?
6. Draw graph of weight versus time for the following: 1) man stands on scale very gently and then gets off again very gently; 2) man jumps onto scales and then jumps off again; 3) man stands on scale and lets his knees unlock so that he drops, then stops. For each of these describe the reasoning behind the graph.
7. The wall of death fairground ride: it's spinning in a horizontal circle. Then the floor that people are standing on falls away. Calculate how fast it has to spin before the floor can fall away without the people dropping out given that: coefficient of friction= μ and radius of the thing= r .
8. If you leave the fridge turned on in a thermally isolated room, what happens to the room?
9. Why can't you light a candle in a spaceship?
10. How many grains of sand are there in the world?
11. What happens if I drop an ant?
12. Why does fire go upwards?
13. Does a cup of hot coffee cool quicker if milk is added before or after stirring?
14. What angle should you aim when trying to shoot a monkey that will fall out the tree the moment you shoot?
15. Why could you not time a pendulum for 10000 swings by watching it with a timer?

МАТЕМАТИКА

1. There's a torus/ring doughnut shaped space station with 2 spacemen on a spacewalk standing diametrically opposite each other. Can then ask a variety of questions such as if spaceman A wants to throw a spanner to spaceman B, what angle and speed should they choose (stating any assumptions made, e.g. that gravity = 0)?
2. What is the square root of i ?
3. If each face of a cube is coloured with one of 6 different colours, how many ways can it be done?
4. Do you know where the multiplication sign came from?
5. If we have 25 people, what is the likelihood that at least one of them is born each month of the year?
6. What makes a tennis ball spin as it's travelling through the air?
7. Imagine a ladder leaning against a vertical wall with its feet on the ground. The middle rung of the ladder has been painted a different colour on the side, so that we can see it when we look at the ladder from side on. What shape does that middle rung trace out as the ladder falls to the floor?
8. Show that no number in the sequence $11, 111, 1111, 11111, \dots$ is a perfect square.