Engineering Academic Enrichment Session

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13:25
Okay, thank you very much. Good afternoon ladies and gentlemen. My name is Maria kettle. Oh, am I muted. No. Can you hear me good okay I'll stagger with the tech minus Maria kettle I'm the Outreach Officer at the Department of Engineering, and I have side hustle, which is physics tube.org is a website full of physics teaching videos for a level physics so my background is I spent 18 years as an A level physics teacher, and now I'm on a mission to persuade everybody that's doing physics that they ought to be doing engineering as well. My mission for this afternoon is that I'm going to give you all a little bit of a taste of a level physics and what a level physics is going to be like, I'm going to give you some strategies for success. And as well, and we're going to have a little think about the nature of learning how do you know when you've learned something because you embark on a course like physics or math sight, there's a big body of knowledge that you have to get your head around. So how do you know when you've learned something. And then, and we can do that through a mixture of things. First of all I'm going to do a form or kind of quite lecturing style of a PowerPoint and I'm going to talk through it, and we're going to think about how wings work and actually while I'm doing this blathering bit. If you can put in the chat. Can we have some theories, please. Sure, like give up and go away. You all know how wings work, can I have in the chat if you think you know how wings work, stick a little comment in the chat, and I'd like to know what, how you think, what you know already how do wings work. So we're going to do, how do wings work that neatly leads into an activity of meet some nasty equations and I will tell you they are quite nasty equations and they won't turn up on any of your a level physics syllabuses none of you, none of those specifications, use the equations that you're going to see today. But we're going to have a quick revision of what how do you manage equations, how do you manipulate them. I'm sure for some of you you'll be like, Why do we need to revise this, but there will be people out there who go, Oh, I really got a reminder of this before. The classes started and started in anger started in earnest with a better term, and then at the final chunk of this afternoon's activity is I'm going to show you how to make some fancy paper aircraft, and give you a link to a way of doing scientific investigation of flight, using those aircraft. Now, before I get distracted by subject proper, I'm going to tell you that for this session, you are going to need the following things you will need a stapler. A good chunky, strong stapler, they're really tiny little wheelie ones probably won't do it. Please can you make sure you've got stapler. You will need A pair of scissors. These can be quite small and weighty they're not an up such a demanding situation. You will need a calculator. So, we are going to do count maths that needs calculators, so you're going to need one of these, you are going to need some a4 paper, and this is my aircraft making paper, so fancy paper printed on one side for origami purposes.

17:28

And this is one of the most important resources that you will have for the whole of a level physics, a level maths, and the rest of your learning and life, why have I got one. I cannot function without this, This is what I call clean on one side paper, so every bit of paper that comes through my house that's printed on the side so that one was wrapping up a newspaper, but inside the envelope is blank. So, cut that to a full size big fat bulldog clip on the top. This is the most important creative resource there is, it's, you can just think with a pen and paper, and if you've got this you can doodle sketches, you can draw designs you can you can work through maths and make it work. So, you will need a way to scrap paper, and if you don't have access to scrap paper, your school does a whole heap of photocopying, they're probably a good source of scrap paper. And if you ask, you'll get it. And that will make all the difference in the world to your sick form career. Right, okay, that's the end of my introduction bit. And so far, precisely, nobody has offered an explanation of how wings works and clearly I'm needed, yay. Right, okay. Oh, we do have one version so wings make em flow move faster over the top, meaning it decreases the pressure over the top, and creates a pressure difference which creates flight or lift actually more accurately because there are some good ideas in there, we do have an idea of pressure difference. That's the good bit of thinking going on that. There is a lower pressure above a wing. And, but actually the speed thing is not what matters and by the end of this session, you'll know that the speed thing is not the important thing. But meanwhile, now I'm going to start off with a bunch of Latin, or at least words in English that have their origins in Latin, and this is with quite a lot of theory flies around about learning and how we learned stuff, and you have learned something. If you can construct your own narrative of those ideas. So, what does that mean, by the end of this session, you're going to know you're going to know how to learn stuff, and what tactics, help you learn stuff, and it's this thing about. You have to invent your own story for the stuff that you're learning. So we're going to, how do you go about doing that, how do you make that happen. So we've got another. We got another fan of speed here somebody else saying wings are shaped to make the air go faster. The air does go faster over the top of wing, but that's not what generates lift. Right, I am going to, um, I've got a script, and I stick to my script, otherwise I go badly wrong. And the next bit of my script says what I'm going to do is share my screen with you and zip through a PowerPoint, of how wigs work so bear with me now while I. That's the one. Right. Share. Okay. And then I have to go. is that, yes, that's gonna work brought. We have a working PowerPoint, this is not a given I'm, I'm not slick with these things. So what you're about to get is how wings work, and I have shamelessly Nick to this professor Holger bubinski is a professor at Department of Engineering, and he does, he calls what he does thermal fluid mechanics. So it's all about energy and transferring energy by transferring matter. But this article about how wings work was published in a journal called physics education, and it's one of the most downloaded. Link, journals, articles in that education journal, and the link to it. This paper will appear in the chat, at some point.

22:16

Right. This is an airfoil section, where it's actually in a smoke visualization chamber at the Department of Engineering, you can see in the middle there, pointing at the screen here which is not effective. But in the middle here that's a bit better. It's an airfoil shape, and then it's called smoke visualization that's actually streams of water vapor flight flowing past the airfoil section there, and it's useful to identify the parts of flow so we have At the front the thing called the stagnation point where the air kind of splits and goes over and under the airfoil section, and the imaginatively named a trailing edge where the two meet at the far end. And we're getting lots of explanations or two explanations in the chat and they both centered on the idea that the top flow is top surfaces longer. So the airflow has to go faster and faster flow gives you lower pressure which indeed it does, and that generates lift, but this is only true along streamline along a continuous streamline the explanation that explanation was invented by Daniel Bernoulli. He was part of a Swiss Family of mathematicians, so they look like they were sort of super geniuses because they got everywhere and did everything, but actually there were loads of them and they all had the same surname so there's sort of Bernoulli equation for this, but nobody's equation for that actually they were different people. So he linked fluid flow, pressure and density, but his work is only true under certain circumstances and actually those circumstances don't apply to wings. And what he did do that was pretty clever because he was sort of something 18th century dude was invented the idea of a particle for fluid dynamics and particle is a little unit of fluid and how big a particle is actually depends really on how much computation power you've got, if you are the Met Office, And you have to calculate the weather forecast for the UK, their cells they call themselves but their particles are 30 Kilometer cubes of atmosphere. If you're dealing with small flows in labs or in chemical engineering plants you might be dealing with much smaller things, but a particle is sort of bigger than an atom and smaller than all the fluid together, but it's a way of thinking about what's happening to each individual bit of the fluid. And if what and what it says in my here is wing demo here, and I am going to try and show you something about how wings work. And, yeah, okay. So to do this I have to turn on this camera, which, and I'm going to turn on some light over here. Yes, that's what I'm after. Right, I'm going to try and if I stop share. Right, I will go back to that PowerPoint in a bit but what I've got here is some things like this. So what I've got here is a piece of cereal packet with some blue tack on the bottom, otherwise it doesn't work. A bit of bent wire which is actually garden wire which lends foam on it, a bulldog clip, and what that was holding is a piece of drinks and cotton reel to sort of stick the whole lot together. This is still the original shape of drinks can, but I've got two of these, so two out of one can, and this one I've carefully flattened out so in aerodynamics terms, this is a flat plate. This is a curved plate. The other bit of kit that I've got for this, is this, this is a top down balance, and if I turn it on. Can you see that yes when that comes into view and you should be able to read that thing. So I'm going to stick on here, it's going to overload. My,

27:00
oh it's cost is constant so chatting No it's not, it's okay. So you can see that I've stuck that on there, flat plate is what you've got on there at the moment, I want this fit in focus, so the flat plate is out of focus and you don't need to see that anyway. The other thing that I've got is this this is actually a hot air gun. You can do this with a hairdryer if you've got one and a hairdryer, is actually a much better thing to deal with because this gets a bit hot and a bit melty but it is a pump, and it pumps, a stream of air out the end. What I'm going to do is run a stream of air over this flat plate and it's been noisy but here goes stream of air.

27:46
You can see that actually that airflow, plus the flat plate, the reading went up ever so slightly, so it was on 13.12 grams, and I cranked it up. And it got to 13.4 Somewhere there. So, in fact the air stream was pushing the flat plate down onto the top pan balance right. Here we go. Second one, this one has got my curved plate. These things are all quite light which is why I have to have a blue tack on the bottom. Otherwise, the air stream just blows them straight away, so again very similar mass to the last 113 point one six here, same strength air stream so I've got two settings but I'm going for the big one because it's go fast, and send that as we go to 11.16, so I shaved, about two grams off there. So, about

16% of the mass some other chunk of the mass. So, difference between these is this one's, They're both thin isn't the thickness of the thing that does it. It's the curvature is the crucial crucial page, that really matters for this. In the interest of saving batteries. I'm going to turn that off for now because I need to come back to that camera for two more bits of stuff that I'm going to do so that camera aren't busy getting rid of,

29:33

and I will go back with the struggle. Back to my

29:40

share. and I want to go from the current slide. It's not the right slide no it's not jump forward whereas Daniel Bernoulli. There he is. Right. Right. Okay so here we are with Daniel Bernoulli. And so he related lots of ideas about fluid flow and pressure. But, and actually ideas about wings are really quite old. What you're looking at here is a wing. So the sail is a wing, and like my wings, it's very thin, it's not the thickness and this diverted path that does it wings work. If you've got, it's easier to see in this drawing of a ship here, a wing sails work in exactly the same way as a wing, they generate thrust at right angles to the dial to the surface of the wing. So, for aircraft that we call that lift and it's a vertical force for air boats and sales. It's a horizontal force and the ship moves through the water, but actually it's working in exactly the same way, and it's not the thickness of the airfoil section that does it, because like with my plates. This wing distance around the inside is exactly the same as the distance around the outside. So, we're generating sideways force and not lift, but we are generating force. Now, this link is notorious for not working. And because it very seldom works is the last words. We get adverts which I don't want. So, I am going to. Can I skip that advert Yes. Okay, here we go This is that same when Tom you saw earlier. And this time it's in action, and you can see, the fluid flow moving over the wing. What happened is Partway into this video is that they pulse the smoke which is a facility that this wind tunnel has got. So any minute now. Now, they start to pulse the smoke, and they slow it down. Here we go, this one is very easy to see. So here comes our uniform winter nice streamlined flow all parallel. The air starts to curve up around the airfoil, and indeed this top stuff is going much faster.

32:27

Sorry to interrupt Maria we can't see her video, could you, you've got one of the PowerPoint screenshot but not the YouTube screen.

32:36

Right. Okay, I will go back to the beginning with that one. Thank you very much for jumping in. Right. Right. We are right I need to go to zoom, and I need to share screen. Try that one right share. No, that is not right. Okay, I will show you how I found this there we go Holger bubinski wings work, it looks like. This is the one that we want, that's actually Holger bubinski standing there if you want to hear his lecture, he is in the running for the role of German comedy ambassador. So actually you might quite like watching him, but I'm going to go with this one. And, as you were. So airfoil in the middle, streamlined flow wafting plastic bit of turbulence and breaking up at the tray trailing edge of the thing, but there we go, we've got, what you're seeing there is the air being diverted around the airforce section. And here we go this is the pulsed stuff. So pulsed flow and you can see very quickly. The top stuffs going faster. Here we go, streamlined flow very slow down this is going to come in, gradually,

gradually creep in. And we're getting this diversion and you can see the top part of this flow is going faster, so no question the airfoil is making the top flow go faster, but is it the spin that generates lift. There is there, if I pause that. You can see that the airflow over the top, has just gone past the wing, while the airflow at the bottom is still going past the wing. So the airflow separating the flow, but air molecules don't have friends, they don't need to meet up at the back trailing edge of the wing, the air just separates over the wing, it does go faster, but faster doesn't generate lift. What does generate lift is curvature, like this, so this curved surface, lots of less flat surface, no lift. Okay, so what generates your lift is curvature. I'm going to stop this share. And then I need another share, and I will go back to the PowerPoint from the current slide.

35:30
Right. Okay, so this link didn't work. Right, here we go I'm gonna throw some maths at you now, and you don't have to write anything down here. So I think sort of try and concentrate on the ideas. There will be later on there will be we will use this stuff but I'll give the stuff that you need. Back to you, again, at the end. Okay, so this is a fluid particle. And we've seen that a fluid particle is bigger than an atom is as fine grained as you can manage within the computation power that you've got, and that is the limit on fluid flow is computation some of the most powerful computers in the UK are owned by the Met Office. Okay. Right, I've got pressure gradient here, and I'm gonna have a quick check, check, of the chat, I'm gonna work on the assumption that you have not covered pressure in GCSE physics because I know that it's disappeared out of a lot of specifications. so pressure is force divided by area, and the classic demonstration of this is you get a sheet of expanded polystyrene thick chunk of expanded polystyrene and you get somebody who's wearing a pair of trainers to walk across it and they walk across it and they make almost no indentation at all, because they train it's got nice big area, their load is spread, and they don't dent polystyrene, but then you put them in a pair of stilettos and get them to walk across the same bit of expanded polystyrene and every step, their heels sink right in and they make huge dents in the expanded polystyrene, but what you've got there is a stiletto here was a tiny little area cenforce concentrated into a tiny area, and it hurts the polystyrene, sometimes you demonstrate that give everybody in the classroom a drawing pin and you hold drawing pin between finger and thumb, and where you've got the point. It hurts and we've got the flat side, it doesn't hurt. Same for side the side, but the, the area matters so that's what pressure is, and it does turn up an A to physics and it's a nice three term equation. Easy. But we've got a pressure gradient, we've got high pressure here, we've got low pressure here so high force per unit area on the left side of my diagram as I'm looking at it low force per unit area on the right side. So we've got a difference in force. And what that does is, got this pressure gradient, it's going to actually exert force on that particle, and you're going to end up with, if you've got an unbalanced force, you do know from GCSE unbalanced force, acceleration, so we've got an acceleration, acting on our particle.

38:31
And

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what, what we've got here is a streamline the particle moving in a nice straight streamlined flow streamline flow is that when you turn on your kitchen tap, and you turn it on, ever so gently. You can get a beautiful smooth stream of water, an absolute like lens it's really no noise from it and it's very

straight, smooth, that is streamlined flow you crank that tap wide open and you will get turbulent flow, the noise level will go up and you can't see through the water stream anymore it's it's messy, it's moving around, it's, it's got variable density through it, actually. And it's a match, that's turbulent flow. So we've got here, streamlined flow it's this beautiful smooth all in straight lines all flowing together. Lovely stream. And, but what about, you've got a curved streamline how you saw in that video, that the airfoil section was putting a curvature into the streamlines. And if you've got an object moving along a curved straight line so this is like a part of a circle in the plane of the paper, and it's moving along that speed v, then you've got to have some sort of unbalanced force to make things go in circles, and you may not meet certainly emotion does turn up if you've done three sciences, you might have met circular motion. If you haven't, it will turn up in your a level spec, and you can go out and do experiments. Preferably, well away from greenhouses and other glass, but if you've got some foam balls, they're the best ones to use those kind of stress balls that are made out of solid polyurethane foam rubber band round them tie a string around them. World them around that ball that you're whirling around goes in a circle, everybody's done. Congrats, string that sort of thing. You feel a port force pulling out from your finger, but the other end of the string that's pulling on the ball is actually pulling back towards the center. So, to make something go in a circle, you need a search centripetal center active force, and if you've got a particle moving in a curved path, there must be centrifugal force acting. So, what have we got, We've got some outside pressure pushing down on the particle pressure from inside the curve pushing up. But the outside pressure and the inside pressure they must be not balanced, that's where you sit, centrifugal force comes from, is that unbalanced pressure. So Holga bubinski said, If a streamline is curved, there must be a pressure gradient across the streamline, with the pressure increasing in the direction away from the center of curvature. So the further out you go higher the pressure gets is that what I've drawn that pressure out is greater than pressure. And this one I'm going to whiz through this quite quickly these diagrams taken from his paper, we've got in the middle areas little black blob is supposed to be a curved plate out where it says, A, you've got streamline flow you've got no curvature you've got no pressure grading, same down at work, at the bottom here at sea, but your air flows going in the direction of this arrow, and in the middle here, you've got this curved air, the air is diverted in various ways. So out here on no pressure gradient in here, you've got a pressure gradient. So when streamlines bunched together, you get higher pressure you see this northern weather forecast alone because you've got this high pressure, and they're busy showing the isobars on the telly weather forecast, really spread out big blob of one loop in closing the hole of the British Isles, and I'm looking at a beautiful sunny day out there. But when it's a windy day, and there's a lot of pressure difference, you get those isobars packed in really closely and they're really curved, and this is the same. These are there are at right angles to the flow of those ice bars, but here you're getting the same thing, curved streamlines give you a pressure gradient.

43:25

So, the pressure at the top is less is bigger than the pressure at B the top of the plate and the pressure at a right at the top of that thing is atmospheric pressure. You can apply the same kind of argument to the bottom, that out of sea, undisturbed flow nothing going on there. Curved streamlines, again, pressure gradient, but this time you the pressure lines and the streamlines are stretched out, you've got higher pressure at sea, then you've got it D. So the pressure at D is higher than atmospheric pressure, pressure D. So, p pressure B, just above the wing is less than the pressure at D. Below the wing, which is above atmospheric This one's below. And the end result is you get lift. So lift is caused by curve curvature, any surface that introduces curvature into a flow field will generate lift, and you know this, if you are the proud owner of a baseball cap with a curved peak, that if you get the wind in the wrong direction across a baseball cap, it's gone. If any of you, science experiment if any of you have got those some baseball caps have absolutely dead flat peaks. Do they blow off less in the wind. Answers on a postcard houses on an email, please come back and tell me. So we get some observations. Oh there's a thing called angle of attack, I'm going to skip over these bit actually because there's a time limit on what I've got to do today and the angle of attack is actually the nose angle of an aircraft. So it's the angle into the wind. Eventually, if you, you get more lift, the bigger the angle of attack, because you get more curvature, but eventually you get a breakdown in the flow, and you get. And the breakaway the boundary layer breaks away from the wing surface. When that happens, they call it sudden and dangerous and basically going to a storm. I've talked a bit about laminar flow this smooth streamlined smooth flow, turbulent flow. Newton's first law of motion Newton's first law of motion, turn up in a level physics, it says that if an object's. Formerly it is. If an object is at rest, it remains at rest and if it's moving it keeps moving in a straight line at constant speed, unless an external force acts. Basically streamlined flow, each particle of fluid is keeping going with its inertia, and it's keeping going and they're all sliding along nicely and smoothly and you get this very smooth flow, turbulent flow, you get viscous forces the goofiness of the water and the interactions and the stickiness of the fluid, not necessarily water, they interrupt the interactions dominate. And, and so the water tech the fluid tends to stick to itself and you get this turbulent flow. Viscosity is how goopy a fluid is so waters running syrup isn't waters low viscosity, syrup is high viscosity. And there are some laws that describe this now, what I'm about to give you is. So yes, some equations that turn up on the equation sheet that hopefully you've had a copy of before this activity, but precise law says the amount of fluid that you can send down a pipe in a second per second volume per second, depends on these factors. So, pi is pi, same circle circle geometry. You're going to have a pressure change along the length of a pipe for stuff to flow. So that matters more pressure faster flow pipe diameter matters, really strongly, if you've got big fat pipes, loads of stuff go through if you've got really skinny capillary tubes, you're not going to get much going through. 128 is a constant, somebody did a load of experiments and that's the number that came up with L is the length of a pipe and that kind of stands to reason if you're trying to build a pipeline across Alaska, you got to put a load of pumps into get stuff moving, whereas a pipeline from your hot water tank to your bump

48:19
is quite short length and you don't need too much pomp to make that happen. And then the final thing is fluid viscosity. So if you're trying to warm, warm water through a pipe, it'll flow relatively easily. If you're trying to pump honey around a honey Processing Factory, you, it will run much more slowly. Factors Affecting turbulent viscosity. So, you can imagine imagine sort of syrup running off a spoon, that's a beautiful laminar flow, high viscous fluid laminar flow, a syrup runs off a spoon and higher speeds, more energy around you get a higher, higher separation. In this case it's this idea of the layer of air closest right the boundary layer right on the surface of a wing is, if it separates away you get this storm, but you get it matters in all sorts of things like vehicles moving on roads high buildings, you know, worry about the airflow pass building bridges are designed in wind tunnels. Because of the airflow past it's really important, big objects produce more turbulence, and I bet all of the schools that you go to have got some narrow gangway between buildings, it's about the width of the classroom that the buildings go way up. And if you're walking through there on a windy day in autumn, there will be a million crisp

packets and leaves and all sorts of really strong wind through that funnel, because the big buildings around it of making loads of turbulence and density so lubricating oils for engines. It really matters what the density is for those. They high density to give you nice laminar flow density matters. These are lots and lots of factors that are just. And they engineering degree if you want to know about that. But this chap is the cavalry he's going to ride to the rescue and sort everything out and give us something we can work with this chap is called Reynolds and what Reynolds did is invent a thing called Reynolds number. Osborne Reynolds is his name. And what he did is come up with this equation. And he says, Are all these four factors but you can punch them into one handy equation and Reynolds number says that Reynolds number is calculated from density that's mass per unit volume. And that's probably one of the first things that you'll learn about in a on an A level course that usually comes in pretty early, but it will be, it is basically if I have a cubic meter of lead, I've got a big hole in my floor because it won't stand it if I had a cubic meter of feathers. Almighty mess, but I'd have, you know, I could pick it up and throw it around the room. And the difference between those two is density obstacle length is length in the direction of the flow flow speed is what, how fast, fluid is moving, and then divided by the disk viscosity of the fluid. And it was huge, that produced a set of numbers than on our own, which numbers are not very useful but the top of this sheet. There is a whole lot of information about Reynolds numbers, and it says if that number comes out to be less than 2000 in SI units, what you've got is laminar flow, it's beautiful streamlined flow, you get almost no way. And you've got high viscosity that the particles of the fluid attending to stick together and move together

52:30

between that 2000 and 100,000. You also get laminar flow, but it generates a week, and then the main drag force is caused by pressure, and if you get greater than 100,000 You have got a turbulent flow, something sometimes this gets manipulated so motorbike racing. It's a lovely sport. What they do is design the motorbikes to be as streamlined as possible so they want the bike to have low air resistance and to move through the air really easily. But as soon as the air leaves the back section of the motorbike. What they do is try and make that air as turbulent as possible. And the reason why is because if somebody is coming up behind, they're encountering this turbulent air, and they're aerodynamic aerodynamics don't work properly, because instead of going into a sort of relatively static air, they're going into this turbulent messy air, and all their careful fairing some aerodynamics and shaping just doesn't work. And in fact it's the limit on how many aircraft you can get into an airport, at any time. On a normal UK commercial airport Heathrow busiest airport in the world, you cannot have more than one flight per three minutes every three minutes, you have to allow three minutes between flights, because otherwise the air around the runway is so turbulent, it's not safe to land an aircraft, they can't predict what the how the aircraft will behave, they have to get three minutes everything settled down the next one comes in three minutes, Settle down. Next one comes in. Right. That's the end of that, I will stop sharing. Now then, there are bits and pieces in the chat, so I've got a whole lot of people saying can't see the video, I presume, those are quite old, and one or two people saying, covered it at GCSE so some specs do cover pressure I have to say I'm very good on the A level spec but GCSE it's been a while since I taught GCSE. Right. Do you recognize this question sheet Have you all got a copy of this question cheat with these problems. So I'm going to pop up the chat again, and somebody says it's not oh it's Lucy so that's Haley, giving you all a message disguised, with a new name of Lucy Cavendish, saying it's uploaded to the website, so hopefully you have seen this, these problems. What I want to do now is have a quick look at some of these problems, and a couple of them probably, and we'll have a go at them and think about how to go about solving them. And then, we will. And then, after we done that, two things one is, if you want to, at some point I'm going to sort of declare that to be a little strip four minute break. And if you don't have a stapler and your scissors. That is your opportunity to dive off and get them. If on the other hand you are super organized and thus, well set to be a good a level student. Then stick any questions that you've got about university courses, a level courses, choice of a levels, and engineering at university is my particular speciality subject, so stick questions about engineering university into the chat. Meanwhile, I have to rig this setup back again, and rearrange the focus on my camera very slightly, so there will now be a pause while you think up questions, we'll find a stapler. I'm going to get my camera, working again.

56:50
That's awake. Yes, we have got this one right next thing I need to do is, Yes I think so. Don't,

57:36
aren't I. Okay, so

57:38
have I got anybody giving me chat or questions about engineering, about a level physics actually is a good one to ask. So does engineering and Cambridge cover aeronautical thoroughly within the cost engineering at Cambridge is a strange thing there is no engineering course at Cambridge on. There isn't one. However, there is a massive thermal fluids group, and what they study is jet engines, and the turbines that run power stations and combustion and propulsion. There's also a massive group studying aerodynamics and how thing, and those are very related things if you think about it the engines and combustion is all about flow of very hot, very energetic gases through engines, so actually that's very real. That's aerodynamics, so the aerodynamics of aeroplane shapes is mostly not very exciting. There is actually a research group that called the silent aircraft initiative, and to build a silent aircraft or quiet aircraft is actually, that's a big challenge. And then there is, and so there's a group doing that.

59:19
But,

59:24
and then there's a structures group, and the physical How do you make this strong light aircraft structure. So, actually, aeronautical engineering is huge, and brings in lots of subjects, and the Cambridge course which is this very general course with specialization after two years, goes, you know which of those specializations Do you want to head for or do you want to mix and you can qualify for the Royal Academy of Engineering and become a chartered courtesy of the Cambridge course, so that works. Right, okay that's disappeared and turned off the video. My camera should be on behind itself before, and now it's not going to behave itself. And I'm going to count to 10 and then I'll give up, do the thing hand waving in front of that camera because

1:00:31
this is the device webcam utility, while you're working. Settings video. Next, is it going to go. I tell you what is what I want to do is model answers to this

1:01:12
model answers to the problems. And what happens if I turn that model doesn't work. And to do that I want a

1:01:25
piece of paper that you folks can see so you can see me working through the problem so my bright idea is to point the camera at the screen. And have you see me doing that in a very low tech sort of way, but it's not having any of it.

1:01:52
My computer sometimes disaster. Right. I'm going to do this in a different way. Okay, this is good. This is gonna be tricky, but I'll do it anyway. Right.

1:02:17
I have got a stack of problems for you here. And the first one says, Now I will tell you about bit of background about these problems. These problems are actually quite weird. I normally use these problems with people somewhere between year 12 Year 13 Thinking about university so people that who are a year into their a level physics. And what happens with them is that they're very very confident about rearranging equations. And here's the thing about a level physics is they give you all the information that you need to answer a question is in the question. And if you think you're short of information for answering the question, you are answering the question wrong. Simple. I used to teach a lad who got six A's, they didn't do a stars in his day, but he did. I didn't teach him he was an outreach volunteer got six A's at a level in all of them except one insensible subjects that are hard. And he used to say, oh they give you the answers in the question. And he was absolutely right. They more or less do. But they, They're not easy. They hide those fun, but the information is all there, you get, if you work through enough past papers you get that you can look at that give me that inflammation that inflammation that inflammation. What do I know what am I want to find out that bits missing. Oh, It's this equation. And yes, you need to know your equations which you do by using them a lot. You need to have quite a systematic approach to solving problems, but it's sort of almost spelled out in the question how to do them and that. Yeah, practice enough you'll get really good at that will happen for you. These problems were actually designed to come a bit outside that partly, I was trying to get people going on improving their study skills. So right at the beginning of this piece, I said that if you're going to learn something, you have to construct your own narrative. That means you can explain to yourself, what you're up to. And the best way to test out those explanations, is to explain it to your mates. So you collaborate, here is Top tip number one for getting good grades are a level physics, and a level maths and chemistry and any other sciences subjects computing that you're doing, collaborate with your mates. When you get a piece of homework. Don't squirrel off, take it home don't lock yourself in a room, eventually you will have to do some of that. But, round up some nights on the course going to sit somewhere, not in the library seat and have librarians go find yourself somewhere comfortable and work out together how to do those problems because in working out together, you've got to talk about what you're doing, talk about how you do it and talk yourself into understanding, that's your goal, you've got to talk. Yes, I used to run a homework club when I was a teacher was a form tutor and I used to say, right, all the rubbish, we had to do in tutorials, rubbish, so I used to not do it, I used to say write

any piece of homework, anybody anywhere has got. Bring your homework to the tutorial, and we'll have a go with anybody's homework we'll sort it out. And this sounds really bold and fortunately there was some native Spanish speakers in the group so I didn't have to do anybody Spanish homework. But what happened more than once, was somebody going, I've got this math so I'm stuck on my maths or physics could be anything but they go through and I'm going, what are you going to do then tell me, how is this what is this I haven't done this in years, so they have to explain to me what they have to do for their homework, but the time explained to me that I need my help anymore they worked out what they're going to do and then find their way. It's that explaining is vital. So, we have got a problem. Now, these problems are a little bit sneaky, because they are, don't give you all the information that you need, they're not a level problems. So, this question says about how fast can a small fish swim before experiencing turbulent flow, about its body. So,

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we are. I need somebody to put in a chat, how big is a small fish. And the thing to remember about this is its length in the direction the fish is moving. So how big is the head of a small fish. There we go. Can I draw a fish, such that you can see it face on view of a fish fin out that way I don't know, there we go fish so fish swimming towards you. How big is that fish. Somebody sent me a dimension in the chat. If not, I shall call on Haley to give me a dimension, are people typing five centimeters right first one in, I've got several people got five centimeters yeah okay, we like that. Now, five centimeters, is it the SI unit. So we're going to say. Now, two ways to write five centimeters, five centimeters is equal to naught point naught, five meters and a thing you will meet real quick. Soon after you get an A level class, You will find this. It is 50 times 10 to the minus three meters. So, five centimeters is 50 millimeters. This thing here is another way of writing millimeters, and it's quite when you're dealing with numbers like this, you're all good mathematicians that's why you're here, you can all swap between these numbers really easily by Christmas, you will be dealing with numbers that are so big, or so small, you can only handle them this way. So, big idea. When you can swap between the two, and you're confident that you can check, because you know what this means you can check, use this notation, it makes life much, much easier later on, and to get confident when you're dealing with numbers like this where you can check, just because you know, means that you'll get it right, later on, make bit future planning in there, make things easy for yourself, okay we are given, so turbulent flow is going to kick in. If so we want to find turbulent flow will kick in when the Reynolds number is 100,000. Okay, so we're trying to find, what do we want, how fast can this fish go before we reach this number. Okay, and we have got an equation for Reynolds number, and I'm going to cheat shamelessly here, because I don't like writing, I'm going to say r is equal to. Now I'm going to use a symbol for density. And then I will explain the symbol. So this is density. And it is mass over volume, which is one of the things you do in your teacher is the way you layout your board is really important you make things really clear and I'm failing dismally with this. So we've got density times L, which we've just decided is five centimeters times v, our flow speed and divided by the viscosity which is eater, we're going to use the Greek letter Eater on a good doubt remember how to write eater. There we go, like that. And it was, Brandon motorbike that puts that as the brand name for their exhausts because it turns up in flow aerodynamics, right. So we're after. This thing here we want to know the velocity. So I've got rearrange this equation. And my experience as a level physics teacher, is that some people are like, rearrange the equation, and other people are like, whoa. And I haven't done this in three months, and yes, so I'm gonna work on the assumption that you're in the category and if you're not, you can just kind of put your brain in neutral for 30 seconds while I do this. So the deal is you can do anything you like to either side of the equation equals symbol, as long as you do the same to both sides. So

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I am going to get rid of this bottom of the fraction first of all I'm going to multiply both sides by eater. So I get e to R, and that gives me eater, r is equal to rho symbol for density it's Greek letter and it's sort of like an upside down six rather than a P L V. Okay, so we're getting closer I want V on its own is what I'm aiming for. So I'm going to divide both sides of this thing by rho L and rho L, they cancel out these two cancel out I didn't cancel out. There we go and we end up with the is equal to e to r over rho L. There we go equation rearranged maths teachers seem to like people phoning in numbers really early on, and then finding the physics teachers and engineers tend to do it this way, and actually in the end, you do whatever way works for you and get and get your head around because what matters is an accurate right answer in an exam, but if you do it this way, you can see what you've done and if I'm trying to mark this piece of work and I can see oh you've rearranged it wrong, then it's easier for me to unpick your and set you on the right track. So, keeping this sort of has the story in it, because it's telling stories. So that's good way to go. Right. So we need to bring in some numbers viscosity of water is 0.001. And these are in Pascal seconds you will meet the Pascal, it is a, it's, it's, pressure is the unit for pressure multiplied by time. That's a Reynolds number.

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Come down from there, and that's the limit, this is, if we if we reach that Reynolds number we've got turbulent flow, so we're going to get out of this the absolute maximum velocity, density of water is 1000 kilograms per cubic meter. And we've decided that our fish is 50 times 10 to the minus minus three meters 10 to the three meters that says our fish is 50 kilometres. I don't think so. So, there we go, that should be to the minus three. And I can't hold up this thing, and drive a calculator at the same time so naught point naught one times 110,000 divided by one to the power three equals divided by 50 times 10 to the power of minus three equals, and I get a V of unit for speed, meters per second. 20 meters per second. That's a heck of a fish is gonna go really fast. So, if this fish goes that fast. We're going to get turbulent flow. 20 meters a second. That's like down a football pitch in five seconds. I'm not entirely convinced by the realism of this answer, but there we go. Right. I have got some model answers for these, I think what I'm going to do is I will give them to Haley I'll ping them over to Haley, and then she can put them up on the website because they're a PDF. I will show you them actually because I use them as a crib, if I'm doing these answers live, then usually I will use them as crib, but my fish is much smaller than yours. What they've got going for them is there actually photocopies of my notes, and they are really old fashioned notes that were made for overhead projector transparencies, so you get a transparent plastic layer and then a paper layer, and I used to write notes to myself on there and then I've included them. So in that one says make reasonable assumptions requirement. In other words, you're asking the students there to make reasonable assumptions. This one. Oh, there's quite a nice. Here I use a lot of subscripts sold out quantities, it's a really powerful thing to do. More reasonable assumptions. I think one of the questions you have to know how long bath takes to run, I have no idea. This is also pretty nifty is I'm rearranging, I'm comparing two equations or two sets of conditions. And actually, for those two sets of conditions, a whole lot of stuff doesn't change it's how fast something goes through a pipe, I think. So we've got a pi, this change in pressure diameters the power 428 That doesn't change, and we've got the pipe length, and that's the same for both sets of conditions. So what

I actually do is work out, is put them all together in one single constant case so it's like my own version of Reynolds number, and put them together, and then it's something like it asks you if you were to fill your pipes in your house with olive oil instead of water, and then try and run a bath. How much longer does it take to run the bar. If it's olive oil squeezing its way through your pipes, and the answer is, at four times longer it'd be cold by the time get in. There we go. Those are I will pass on. Right. What will happen if a fish hit turbulent flow, what will happen is that the flow around the fish. So, before the flow goes turbulent you'll have a stealth fish, it can wiggle through the water, absolutely doesn't disturb the water around it goes really smoothly, doesn't make noise doesn't create bubbles sneaks through the water stealthily, avoiding predators. If it speeds up, it will start to make you get cavitation

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and mess messy noisy flow. And you do get little vacuum bubbles forming the water because of the mess, and so the fish will make this noisy flow, and if it's a predator fish won't care of tween rabbits play, but if it's a prey species, it's going to give away its presence by noisy flow that answer that one hopes. Right, well I have promised to do is show you folks how to make paper aircraft, and one of the things that might appear in the chat now is a set of videos that repeat how to do what I'm doing now. If you want a taste of a level physics II style work, and possibly

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basis with extended project qualification. Then, there we go, the videos are up. The third of those videos is with is how to make these wings, how to make a launcher but actually it's not very good launcher that I make, because it's a challenge to make a decent launcher was actually what I was doing so I made a rubbish launcher and challenged people to make a better one, but it's a launcher. The third video shows much better launcher, and how to make science project out of investigating paper aircraft question here. Formula One cars and cars that require lots of downforce, do the wings, act, opposite to the way aircraft wings do exactly so yes indeed, that's exactly what they are now, upside down wings, and they are pushing the cars down onto the road and sticking them. Right. It would be really good for the purpose of making an aircraft, if I could persuade this camera to work, but I have a bad feeling that it's not going to play ball at all. Yeah. What I'm going to do now is show you how to make paper aircraft, and I have to do this in the way, I've just done those problems, and it's going to be just as awkward. There we go. You need a sheet of a4 paper. So I have got paper that's printed on both sides, because it is helpful to show you what, what's going on. What you need to do with this is, take your sheet of a4 paper. Do you all have stapler and scissors, the crucial things for this. Okay, I hope so. Right. What I'm doing here is folding, I've got a sheet of a4 paper and folding it in half, so I'm folding it to a five size. This is, yeah. It's very annoying, not to be able to get this video to go, not least because it was working beautifully earlier. And it would be so much easier. I might try it it's not gonna work. I've got a bad feeling that I've just worked out why it wasn't working. I have an app on my computer for running the camera, and if the app is up. Then, if the app is open, then it doesn't work as a means of as a webcam, and if it's and I didn't think I had it open, but perhaps I did. So try that. Right. myself into this meeting, cameras on recording in progress. Right. do we get this camera start video. Fantastic. All right, here we go, cooking on gas sheet of a4 paper folded. I need to zoom right out for you to see this silver metal my desk as well. Right, zoom right out is that in focus, that's, that's good enough. That's about right. Stick that on there. Go away. It's the app trying to wake up. We're back again and I shot it bright. Okay so, piece of a4 paper folded in half. The way. Right. Some rules of origami apply to these aircraft, You must

make all your creases corners match creases nice and sharp. So, a four to a five, is what you're doing. And just to do that again, a four to a five, match the corners, folded nice and sharp. Away We Go, run your finger now, up and down the crease, keep it sharp. Okay. When you've done that, the next thing is, I've got this flapped away from me like that. I'm going to take this corner here and fold it down like that. So I'm making a 45 degree triangle. There we go.

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shotcrete crease along there and you can see the pattern on my cardboard because it's a bit of patterned paper. This is a symmetrical aircraft so what you need to do is flip the whole thing over and do the same thing again.

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So 245 degree creases and nice and sharp, like that. And just in case you missed that, I'll leave that on screen, I hope. Shut it sideways, do the same thing again with this one. So I've got this my open corner, there's my crease. Fold that down to the crease.

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Nice and sharp crease corner crease. Fold that down to the crease. Right. Okay. Now the next thing I'm going to ask you to do is the trace step in the whole thing. So what I've got here is a trapezium. Okay, so this here side down the middle of the trapezium, that free edge there needs to fold that so I'm going to take this triangle, and make a long thin triangle. So, rectangle, triangle edge between the two fold it over like that.

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Okay. Symmetrical aircraft so you flip it over, rectangle, triangle edge between the two fold this age up to that fold there. So that was

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edge up to that fold, nice sharp fold if you can as sharp as you can manage

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it. For sat down, make that crunchy. Okay, so that again. Don't that one somewhere where it's in view just about right. Okay, So same again, you would go, rectangle, triangle edge between the two fold it up to this fold. So I'm going like that. and then here this is my original fault here. I've got a little Sully's triangle. Bigger scaling one here. Okay, final time I'm going to do this rectangle, triangle edge between the two, up to that crease there squish that into place. Right. Squash quite hard I've got thick cardboard because it's got these nice print songs to work quite hard. Now I've just asked you to bring some scissors. And this is, we're about to break the rules of origami. And if you flatten this right out this way. So you should have a little square here. If you don't, you've probably folded these triangles the wrong way, it's quite easy to fold them, so you end up with two triangles at the edges here should have, square in the middle there. Okay, what we're going to do is cut along this very first fold that you made. I'm going to start cutting just here at the tip of this thing, and I'm going to cut up to there, which is where the, where these bits meet. So there's a drop of ink there. So I'm going to cut along this line along the original fold. Snip, snip, snip, just took

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that, and then fold that on back up again. And in case you missed that,

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flatten this out, and I'm going to cut the sort of diagonal of this square here. So, snip, snip, snip, snip, snip, two. Okay, like that. Right. And the next thing is watching a bit of cracking through this but there is a video you can go back and watch it again, right, the next thing is I've got here a sort of long thin triangle. What I'm going to do is fold that month in triangle in half down the middle here I'm going to make a valley fold. And if I didn't have a cut, I couldn't make this fold. So that's what we're actually making here is these are the spars, so it's the leading edge of the aircraft wing. And it's one of the many things you can muck about with with these aircrafts you can chew them, and you can adjust the design and then because you can adjust the design you can pick one factor and say, I'm going to vary the mass of paper per unit area that I make it out of so I go like tracing paper chunky cardboard newsprint ordinary typing paper, you can make a whole series of aircraft and see how much mass affects flight and it actually affects it really strongly. You can do things like vary the wing area and see how much that affects, so I folded that one in half, symmetrical aircraft so long thing triangle here. Fold this one in half. Three YouTube video links are, how to make the aircraft. How to make a battleship. And then, how to make your project scientific storing a much better launcher so watch all three before you make launcher. Right. I'm going to do the same again now with this one. So I've got this, it's easy to see because this is darker, long thin triangle here, and I'm going to make a valley fold and fold that bit there, and the bit flips underneath it. fold.

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Alright, turn it over, do the same again I've got this long thin triangle and then make a valley fold like that.

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But once you've got that far, and you've got those folds made you do the same again you sort of take this chunk here, this chunk and you roll it back on itself like that and you should find that the cut that you made and just here. Turn this over table this big chunk here. So I've got shaped tight and just roll it over. Okay, but show you again because it's good to repeat these things so that one's in shop so you can see it right okay so I'm going to take this chunk here and roll it on itself and enough back on I make this sort of super tiny shape, just briefly, and then turn the whole thing over, and this chunk here is big wedge of cobble here paper here. Okay, so far so good. Right, I've now got two aircraft ready to go. The next thing I'm going to do. I'm going to turn this random thing I'm working upside down, is, next thing you do is you'd cover wing shape and wing shapes are anything you think it's very ugly wing II. The this original fold here, very first fold a four to a five that you made is important structure of your aircraft so don't cut too much of that edge away. But then you can sort of opportunity for creativity, make a wind shape. You don't actually have to draw it first I draw it first because I'm doing this as demonstration, and I want to show you the sort of shape that works, but just chop that bit off. Like a week. This one. Again, I ended up doing an awful lot of Winslow's prep service I'm going to try and be a bit more imaginative. Not to be much more imaginative but I've got the kind of narrower piece here. And at the extremes. I would go chop that out. And I'm chopping through two layers of card here. So I'm

making a symmetrical aircraft. Right, these bits, took them away. They are redundant, right, the next thing you're going to do is these little triangle bits here, fold them up. Okay, so you've got here and that's just two layers of paper, little flappy bit folded up, but really all you're doing there is folding them out of the way. Okay, so here I am again, two layers of cardboard here. I'm gonna fold it along that edge there. Up and out of the way. And the same here. There's the edge two layers of cardboard, folded up out of the way. The next thing is, I'm so glad I'm not trying to do this. Indeed. To me this bit. Right. What I've done now is flatten out my aircraft completely, and actually I'm going to turn it over that way up. Check this one. This is where the stapler comes in. There we go. What you've got here is a whole lot of aircraft papers springing apart. So what you do is put staple right through the middle, to hold the whole lot together. And ideally, you've got this line of symmetry here. So ideally, keep your staple symmetrical. And I have to go through a massive amount of cardboard here and it's quite tricky

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succeeded. Actually I cheat here because this card is so thick. Stout, that pliers are my friend. And I squash that step.

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Right. Same again demonstration again. What I've got here is these bits are now these triangular bits of folded out of the way so I can get the whole thing completely flat. And I like the plain staple on top so I do turn out to do this, but I'm going. It's not going to work for staple through there. It's not in brilliant focus, but on the line of symmetry as symmetrical as I can manage it. It's come all the way through. So I squash those in the pliers if you're using ordinary typing paper. But if you're doing what I'm doing, working with this quite thick card it's not so eating right, and the next thing is, but this is more or less finished aircraft. There are some things you can do with it, that are quite interesting. And I'll show you how to launch them. This staple means that you can bend the v shape into aircraft. This is called a dihedral. Come over here we show you this, like the dihedral that's how I do it better, dihedral means V shaped and some birds have V shaped wing some aircraft B shaped wings, but they would go out and put a V shape in there, and this age stability. So, if my aircraft starts to roll this way, a horizontal wing has more lift. So if my aircraft starts to roll like this, this wing has more lift will come up this wing has less lift, and it will self correct. So, pigeons really watch pigeons flying, they have seriously V shaped weights. Right, next thing you can do with this is, We've seen that curved air is what really matters to get lift, so you can go squashing curvature back into these aircraft. You can squash the spars on here. So having put really sharp neat creases into my spars are now going to try and squash them a bit fatter again. And so I'm making a curved surface, and I'm making lift. It's quite hard to do that. Right. And then finally, to ranchi this, I can stick my thumbs. Underneath that, and maybe even stretch the paper a bit, but definitely put curvature in to that way. And so these are all things that you're controlling who there's paper darts that you made we fold it a long ways in half and then loads of triangles, flying really brilliantly. But, there's no control, these ones, you get a lot of control. They have a low glide speed darts, have a high glide speed there so triangle ones. So, your average census assumption here, average teenage boy. Good old lob belt out there, and a dart with high glide speed will go really well if you throw it fast. These have a load lightspeed. And so, you have to sort them on the air a bit, and actually these ones are heavy and don't fly very well, but I've got my thumb to the finger on top of the fingers out of the way. This one, limited adjustment to turn in the air, you can do things like roll up the ends of the wings, if it veers one way you roll up the end of the wings and you can steer them a bit so

they're quite nice to play with. Right, I am clock watching is firing on half past three. Which is when I'm supposed to finish. I'm actually not going to finish immediately I'm going to tell you some useful things. Thing number one is how to get top grades at a level. So we've had a look at equation skills we've had a look at flight.

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You will get set homework, Weekly, when you do tests every so often with those homeworks, start high aim high and Chase, every single mark so if you get 97% for a piece of homework. You go back to your teachers, and you say, why don't you give me 3% Your teachers will become better teachers if you chase them like that to chase every mark, because then you know what you're not good at, and how to get better. Second thing come Christmas 2022 So that's Christmas in your a two year that Christmas holiday is when you start your a level revision for all your subjects, and by the end of that holiday, you're not going to pass papers and all that golf yet, but what you do know, is he know your exam timetable that you'll be published, if it isn't published already will be published pretty soon actually. So, no one all your exams are, know what you've covered already what subjects you've covered know what topics you've still got to go because there will be something Christmas you haven't looked at yet know where the holes are in your knowledge, what are the holes that you mean, you're off sick in March with loads of flu. What did you miss that, how are you going to catch that up. By the end of Christmas 2000 to 22, you've got to have a map for how your revision is going to be. And finally, the last suggestion for how to get top grades at a level, you should, much more fun, you teach your mates. This thing of, if you can tell the story of the ideas you can explain it. You understand it, if you can explain it to an eight year old, you understand it really well, if you can explain it to your mates it's informal it's quite fun you can use like casual language, but you're explaining it, and you will find it's hard, it is really hard but it is the best way to revise an excellent so a good way to prepare for university interviews because you're talking out loud, you're explaining out loud. Right. I'm going to push off, I think I will. Haley, do you want to jump in and do anything. And yeah, I

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just thank you so much that was really interesting. Thank you, Maria, I tried to build my own paper of fame but failed quite miserably, but hopefully everyone had what everyone else had more luck with the paper I think. But yeah, thank you. The session will be recorded and will be recorded and I'll put all the resources, right, as mentioned, up on the website as well so you'll have access to them.

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But thank you very much and this thing, over to you, and thank you very much. Okay. All right, bye everybody. Take care everyone. Bye.