Oxford Physics
Mock Interview Pack
for Teachers

STUDENTS: THIS IS NOT FOR YOU

This pack is intended to help teachers who need support with running a mock interview. If you cheat and look at these questions and solutions in advance, you are wasting a valuable opportunity.

Contents

Introduction

This pack is intended to provide the resources needed for a teacher to run a mock interview for a student who has applied for Physics at Oxford. It has been created by the Physics Department's Access Officer. The assumption is that you are a physics teacher, but we have explained everything in some depth all the same.

We hope this pack is useful, but you should also check the information available at https://www.physics.ox.ac.uk/study/undergraduates

We cannot interview everyone who applies for Physics or Physics and Philosophy here, largely because the interviews are an intensive process that take a lot of resources. We therefore shortlist based on a candidate's score on the Physics Aptitude Test alongside information from their UCAS form.

Shortlisted candidates are invited to interviews in around mid-December (the dates will vary from year to year, so make sure to check the website). They will often have two interviews with one college and a third interview with another college. In 2021, all interviews will be held online. Interviews are essentially academic and are likely to largely concentrate on discussions of topics in physics and maths. This pack provides some mock physics and maths questions, of the sort that might be asked at interview.

We have provided sample solutions, but these do not represent the only way to tackle a problem. If you or your student has an alternative method, we would love to hear it so that we can include it in future editions.

We hope this pack is useful to you. However, if you have suggestions on how to improve it, or any comments on this resource, please do email us at schools.liaison@physics.ox.ac.uk.
This document was last changed on 22/11/2021 by Kathryn Boast.

Admissions Criteria

The interviews are assessed against our Admissions Criteria, which are what we are looking for in potential students. These are:

- Motivation: a real interest and strong desire to learn physics.
- Ability to express physical ideas using mathematics; mathematical ability.
- Reasoning ability: ability to analyse and solve problems using logical and critical approaches.
- Physical intuition: an ability to see how one part of a physical system connects with another; and to predict what will happen in a given physical situation.
- Communication: ability to give precise explanations both orally and numerically.

A student who demonstrates these criteria in the interview, e.g. by clearly explaining their thinking as they reason their way through physics and maths problems, is likely to score well.

Notes on interview format

Interviews in 2021 will be held online. More information about this can be found at https://www.ox.ac.uk/admissions/undergraduate/applying-to-oxford/guide/interviews

There are often two interviewers in the interview, though there may be more. They want the student to feel relaxed so they may start with a general non-academic question, or maybe something based on the student's personal statement, though equally they may jump straight in with an academic question. These are most often physics and maths problems that are designed to test how you think and how you explain your ideas. The interview could last around 20-30 minutes. It's often a good idea for the student to write things down while they are explaining their thinking. The more they explain their thinking, the better.

There is no formal syllabus for the interviews, but knowledge of the PAT syllabus material will be assumed. The PAT syllabus can be found here:
https://www.physics.ox.ac.uk/study/undergraduates/how-apply/physics-aptitude-test-pat/pat-syllabus

A good mock interview probably:

- lasts up to thirty minutes
- is led by someone the student doesn't know very well
- ideally has two interviewers: one asking questions and one taking notes
- might start with a general / introductory question to set the student at ease (though this should not be about the college they're being interviewed in). It could be about something in their personal statement, or it could just be a simple maths question to get things started.
- uses physics and maths problems
- has the student writing and drawing diagrams to explain their thinking, perhaps on a shared virtual whiteboard for an online interview
- probably covers more than one question / problem. It's fine not to get through all the questions in that time, but if one is taking too long, feel free to move on.

More resources
There is lots of information online about interviews, and lots of unofficial “sample questions” but take care to stick to reputable sources if you’re looking for information.

The university pages on interviews set everything out clearly. They also include physics sample questions, and you could look at some of the maths ones too if you wanted:
http://www.ox.ac.uk/admissions/undergraduate/applying-to-oxford/guide/interviews

There is lots of detailed information about the Oxford Physics admissions process on our website:
https://www.physics.ox.ac.uk/study/undergraduates/how-apply/admissions-procedures-physics-courses

There is also a mock interview available here: https://www.youtube.com/watch?v=CLz3a8NYtik

Some of the advice about preparing for the PAT is also applicable to interviews:
https://www.ox.ac.uk/admissions/undergraduate/applying-to-oxford/guide/admissions-tests/pat

The Questions

Question 1

Sketch the graph of $y = \frac{\sin x}{x}$.

Differentiate the original function. (Optional: can you draw a graph of this differentiated function?)

Square the original function. Sketch the graph of this squared function. Is this pattern familiar?

Question 2

When an object is submerged in a fluid, an upward buoyancy force appears which is equal to the weight of the displaced fluid.

Bearing this information in mind, consider the following question:
An object of mass $25\ \mathrm{kg}$ and density $50\ \mathrm{kg/m^{-3}}$ is tethered to the bottom of a tank of water by a string. What is the tension in the string?

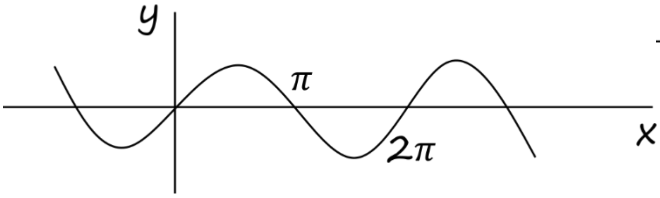
Question 3

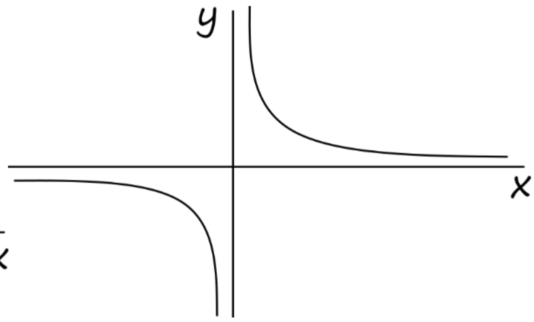
How high up a mountain could I go having eaten a banana?

Question 1 – Full Solution

Sketch the graph of $y = \frac{\sin x}{x}$.

Start by sketching $y = \sin x$ and $y = \frac{1}{x}$





In the limit of small angles, $\sin x \to x$.
Hence as $x \to 0$, $y \to \frac{x}{x} = 1$.

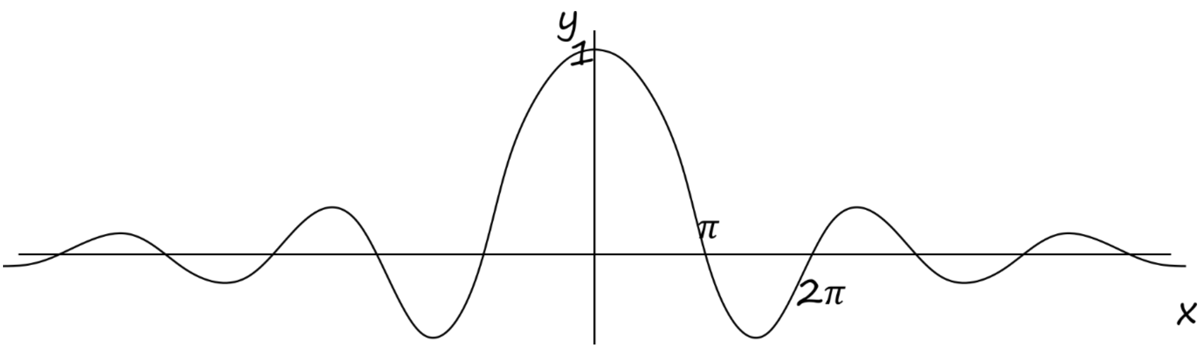
All the other times when $\sin x = 0$, $y = 0$, i.e. at $x = \pi, 2\pi, 3\pi, \ldots = n\pi$ where n is an integer. So the function will oscillate.

The amplitude of the oscillation will depend on the magnitude and sign of $\frac{1}{x}$. Close to zero, the amplitude will be larger and as x increases, the amplitude will decrease.

Both $f(x) = \sin x$ and $f(x) = \frac{1}{x}$ are odd functions, i.e. $f(-x) = -f(x)$, so their product is an even function, i.e. $g(x) = g(-x)$, and the graph is symmetric about the y-axis.

So we need a graph that

- goes through $y = 1$ at $x = 0$
- has y=0 at all other x=$n\pi$
- has decreasing amplitude as x>0 increases
- is symmetric about the y-axis.



Differentiate the original function. (Optional: can you draw a graph of this differentiated function?)

To differentiate $y = \frac{\sin x}{x}$, we can use the product rule as follows:

$$\frac{dy}{dx} = u\frac{dv}{dx} + v\frac{du}{dx}$$

$$u = \sin x \qquad v = \frac{1}{x} = x^{-1}$$

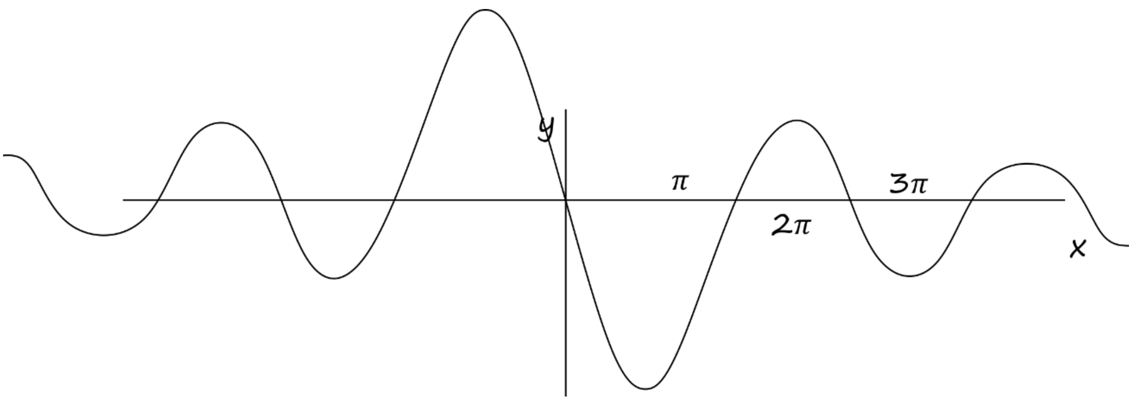
$$\frac{du}{dx} = \cos x \qquad \frac{dv}{dx} = -x^{-2} = -\frac{1}{x^2}$$

$$\frac{dy}{dx} = \sin x\left(-\frac{1}{x^2}\right) + \frac{1}{x}\cos x$$

$$= \frac{x\cos x - \sin x}{x^2}$$

Drawing the graph from this function is tricky, but the differentiated function is just going to be the gradient of the original graph. So we're looking for a graph that:

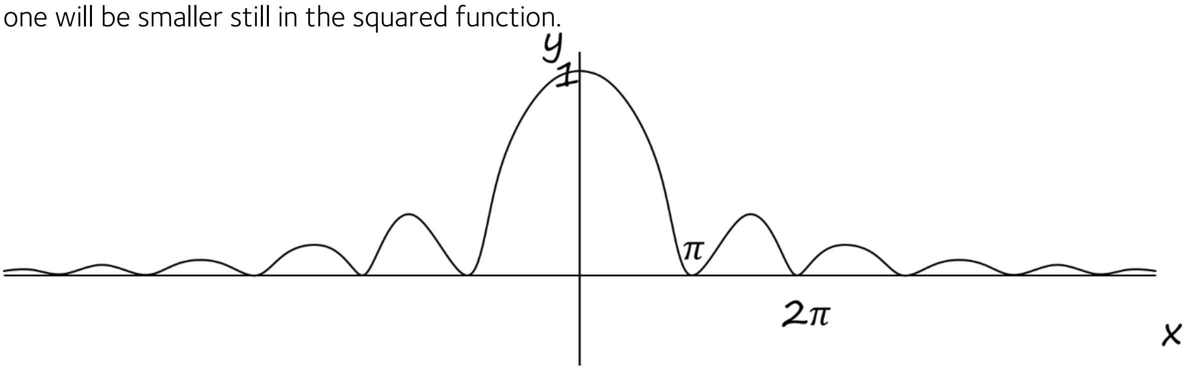
- is zero at all the minima and maxima, i.e. at $x = 0, \frac{2n+1}{2}\pi$ for integer n
- has maxima and minimum at x=$n\pi$ for integer n>1
- has a gradually decreasing amplitude but oscillates about $y = 0$
- is negative for $0 < x < \frac{3\pi}{2}$



Square the original function. Sketch the graph of this squared function. Is this pattern familiar?

If we square $y = \frac{\sin x}{x}$ we get $z = \frac{\sin^2 x}{x^2}$.

The graph of $\frac{\sin^2 x}{x^2}$ will, like the original, have zeroes at x=$n\pi$ for n>0. However, it will always be positive. Where the amplitude was 1 before, it will remain so. However, any amplitudes smaller than one will be smaller still in the squared function.



This is the pattern you get when you have single slit diffraction.

Question 1 –Hints & Prompts

To begin, they might like to sketch the two functions, and consider what happens to the amplitudes when you multiply the two together at any given point.
For each graph, if the student seems stuck, suggest they think about key points:

- What happens when x=0?
- At which points will y=0?
- Is there any general pattern in the amplitude?

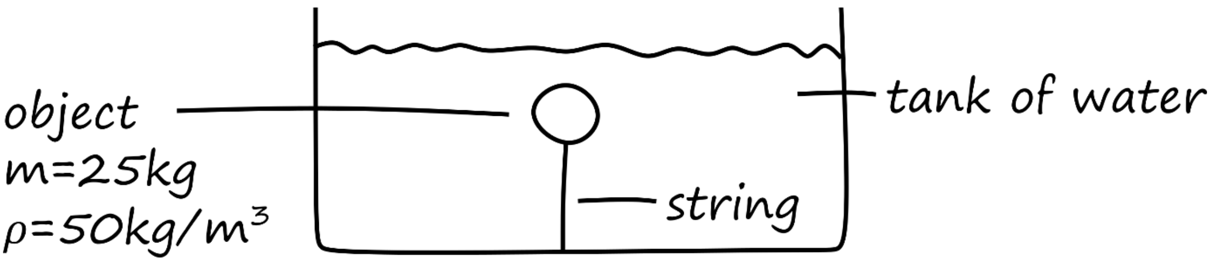
For differentiating the function, they should know the Product Rule, but you could give it to them if they are getting mixed up.

They may or may not recognise the single slit diffraction pattern in the final part of the question – that's ok!

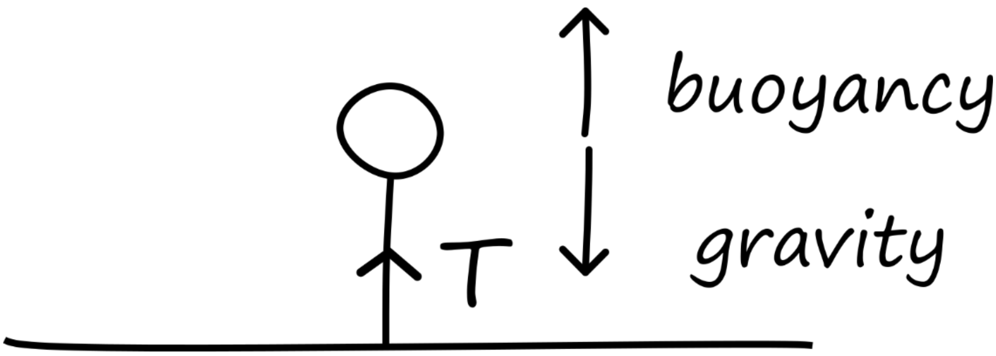
Question 2 – Full solution

When an object is submerged in a fluid, an upward buoyancy force appears which is equal to the weight of the displaced fluid.
Bearing this information in mind, consider the following question:
An object of mass $\mathbf{25\ kg}$ and density $\mathbf{50\ kg/m^{-3}}$ is tethered to the bottom of a tank of water by a string. What is the tension in the string?

Start by drawing a diagram.



The gravitational force is equal to mg.
The buoyancy force = weight of water displaced.
Drawing a force diagram for these forces:



To find the buoyancy force, we need to calculate the weight of the water displaced.

The volume of object V_O is the mass m_O divided by the density ρ_O:

$$V_O = \frac{m_O}{\rho_O} = \frac{25}{50} = 0.5\ \mathrm{m}^3$$

The mass m_W of water displaced is the volume V_O of the object x density ρ_W of water:

$$m_W = V_O \times \rho_W = 0.5 \times 1000 = 500\ \mathrm{kg}$$

So the net force $F = -m_O g + 500g = 475g$.

This must be equal to the force in the string:
$T = 475g\ \mathrm{N} = 4750\ \mathrm{N}$ for $g = 10\ \mathrm{ms}^{-2}$.

Question 2 – Hints & Tips

Students should draw a diagram and be expected to work out simple calculations without the need for a calculator.

The key is can they work out that they need the weight of the water displaced, rather than just the weight of the object.

You can tell them that the density of water is $1000\ \mathrm{kg/m^3}$ either at the beginning or when they need it.

It's good practice to give different labels to the different quantities, e.g. don't use just 'm' for both the mass of the object and the mass of the water displaced.

The system is in equilibrium so the forces must balance.

Question 3 – Full solution

How high up a mountain could I go having eaten a banana?

The energy required to lift something up is equal to its change in gravitational potential energy.
$E=mgh$
where E is the energy in J, m is the mass of the object in kg, g is the gravitational constant and h is the height change in m.

Estimate: Let's go for a mass $m=60\mathrm{kg}$, and $g = 10\ \mathrm{ms}^{-2}$. So $E=600\times h$

Assumption: let's ignore other energy loss, e.g. due to human inefficiency (heating) or energy required to climb other than vertically. So all the energy from the banana is converted into gravitational potential energy.

So, how much energy is in a banana?

Estimate: something like 100 Calories = 100 kilocalories?
Sense check: The average person is recommended to eat something like 2000 kcal per day, which at our estimate would be about 20 bananas. This seems vaguely reasonable.

We need our GPE in J, so what is the conversion between kcal and J? I don't know it, but I can try to figure it out.

It would be reasonable to ask the interviewer what this conversion is if you don't know it, though you can take steps towards figuring it out.

I happen to know that one calorie (NB not kcal) raises $1\mathrm{g}$ of water by $1°\mathrm{C}=1\mathrm{K}$.
Specific heat capacity is given in terms of $\frac{\mathrm{J}}{\mathrm{kg\ K}}$ – let's try and use this to convert between kcal and J.

The specific heat capacity of water is approx. $4200\ \frac{\mathrm{J}}{\mathrm{kg\ K}}$. This is equal to $\frac{1\ \mathrm{cal}}{1\mathrm{g}\times 1\mathrm{K}}$

$$\frac{4200\ \mathrm{J}}{\mathrm{kg\ K}} = \frac{4.2\ \mathrm{kJ}}{\mathrm{kg\ K}} = \frac{4.2\ \mathrm{J}}{\mathrm{g\ K}} = \frac{1\ \mathrm{cal}}{\mathrm{g\ K}}$$

So $1\ \mathrm{cal}= 4.2\ \mathrm{J}$.
Hence our banana contains about $100\ \mathrm{kcal}=100\times1000\times4.2\ \mathrm{J}=420\ \mathrm{kJ}$. *There's another approach for finding this figure given in the Handy Hints and Prompts.*

If this is our change in GPE, E, then

$$h = \frac{E}{600}$$
$$= \frac{420\times10^3\mathrm{J}}{600\ \mathrm{kg\ m\ s^{-2}}}$$
$$= \frac{4200}{6}$$
$$=700\ \mathrm{m}$$

Sense check: Ben Nevis is about $1300\ \mathrm{m}$ high, so this seems not unreasonable. It is higher than we might expect,(most climbers would take more than two bananas to get themselves to the top of Ben Nevis) but we have assumed a much higher energy conversion from banana to height climbed than is reasonable.

Question 3 – Handy Hints and Prompts

If the student doesn't know where to start, get them to think about ideas around energy. Possible (very basic) prompt questions:

- Why do we eat?
    - *For energy*
- Do we eat more when we exercise?
    - *Yes, we burn more calories so we eat more to compensate. We use more energy doing exercise*
- Is it easier to walk on the flat or up a hill?
    - *Walking up hill uses more energy*

Then try to get them thinking about gravitational potential energy and the relationship between the energy needed to lift something and the gravitational potential energy it has.

- When we're climbing, we're essentially lifting ourselves up the mountain. How much energy does it take to lift something up?
    - *Gravitational potential energy, E=mgh*

If they can't remember the formula for GPE, you can give it to them, though this is something they probably should know from the PAT syllabus.

Ideally they will tell you what approximations they are making when they use $E=mgh$ in this context. If they don't it might be good to prompt them. This will show some of their physical intuition – what are they ignoring by using $E=mgh$? What's the difference between this idealised case and the real world? (Inefficiency of the human body in climbing.) This can also be a question for the end of their estimate, if this isn't the best time to ask it. It's fine for them to want to put in an extra factor to account for the efficiency if they want – anything down to about 10% seems reasonable enough to me.

If they start using numbers, prompt them to estimate a sensible mass (50 – 100kg is OK, would expect 60-70 kg to be the most sensible figures). As it is an estimation question, we would expect a mass to the nearest 10kg. Similarly, because it is an estimation question, they should use $g = 10\ \mathrm{ms}^{-2}$. They might not start using numbers in the formula yet though. It's fine for that to all come at the end.

The next step is to work out how much energy is in a banana.

- If they start talking about Calories (note capital C), you might want to correct misconceptions around Calories and kilocalories. When we talk casually about energy in food, we usually use Calories. 1 Calorie = 1 kilocalorie. 1 calorie heats 1g of water by $1°\mathrm{C}$. Or you can leave in this potential factor of 1000 error, and see if they spot it later when they sense-check their answers.

They may either think about it in terms of kcal and then convert to Joules, or they may try to think of the energy in Joules directly.

If they can't think of a starting point for calculating the energy in a banana, you could ask:

- Do you know how many Calories are in a banana?
- Do you know how many Calories are in any food? How does that relate to a banana?

- Do you know how many Calories you are meant to eat in a day? How many bananas do you think you would need to eat to see you through a day? So how many Calories are in a banana?

Then you could prompt with the relationship between Calories and kJ, or you could push them down the route of finding the relationship through the specific heat capacity of water (=4.2kJ/kgK).
Or you could go along the route of finding it directly through an experiment. A fairly common school science experiment is to set fire to some food and see how much the burning food heats up some water.

$$\text{Energy transferred} = \text{mass} \times \text{specific heat capacity} \times \text{temperature increase}$$

$$\text{Energy transferred (J)} = \text{mass of water (g)} \times 4.2\frac{\text{J}}{(\text{g}°\text{C})} \times \text{temperature increase (°C)}$$

Typical numbers for this are 0.5g of food increases the temperature of $10\ \text{cm}^3$ of water by $20°\text{C}$. In such a case, energy content of food would be $1680\frac{\text{J}}{g} \approx 2 \times 10^3\frac{\text{kJ}}{\text{kg}}$. So if a banana weighs 100g, it contains approximately $100{\times}2\ \text{kJ}{=}200\ \text{kJ}$. (This is a reasonable value, but anything with this order of magnitude would seem OK.)

If they haven't done the experiment, or can't remember sensible numbers for it, you can prompt them to either guess (e.g. What volume of water might be in the test tube? How much does a small piece of food weigh? How much hotter is the water likely to get – what would you expect to see?) or you could give them the formula and some numbers.

Once they have a number for the energy in a banana in kJ, they can put this back into their formula $E{=}mgh$ to find h.

A reasonable answer is around a few hundred metres perhaps, depending on exactly what assumptions they have put into the calculation, especially if they have included a factor for efficiency.