Keble At Large

Physics

Applicants Guide

General information

Deadline for application	15^{th} October
A-Level requirements	A*AA - Physics and maths must be taken and the A* can be of these. If Further maths is offered this can also be the A*. Note **further maths is not required.**
Aptitude test	Physics Aptitude Test (PAT)
Course Length	MPhys - 4 Years

UCAS Information

- All university applications in the U.K. must be done through UCAS and all applications to Oxbridge must be done by the 15^{th} October (for 2016 year of application). Applying to Oxford you will need to submit,

  1. All external exam grades.
  2. A personal statement.
  3. A written exam (the P.A.T test).
  4. A reference written by the UCAS referee.
  5. Personal information.

- The course code is F303, note only the MPhys is currently being offered.
- Further maths is not required of applicants, but it would always be beneficial to have as the more maths practice you do the better you get.
- As well as this for good enough applicants there will also be an interview.

Personal Statement

The personal statement is one of the first things tutors will see, it is sent in via UCAS and should be about your passion for physics. They majority should be about physics with a minority about extracurricular activities.

- The most import part of the personal statement is conveying your passion for physics.
- Make sure to give lots of good examples to back up your argument, quote books that you have read and maybe external lectures you have seen.
- If you end up teaching yourself any further maths modules or other exams this can be a good way to show passion for your subject.
- The tutors are looking for what you have done beyond A-Level. Work experience can be incredibly useful and many university departments will offer outreach to school students.
- The personal statement will not be as useful to tutors as the interview and P.A.T test, but it is their first impression of you and so should be as good as it can.

- Although coding experience is not required prior to starting if you have done any it might be useful to mention here as coding plays a large part of many scientist life's.
- If you have done a EPQ or similar this is the place to talk about it. They are good at conveying interest and hopefully after researching a topic so in-depth you can appear relatively knowledgeable about the subject.
- A brief section on your extracurricular activities to show other qualities about yourself can be included at the end, e.g. any music or sport that you do.
- Try and get across your character in the personal statement, at the end of the day if you get in the tutors will spend a lot of time with you and they want to know if they can work with you.
- Don't look at student room for other peoples' personal statement as lots of people lie to try and intimidate others (Also they will lie about how easy they found the P.A.T).
- Don't lie as tutors will ask question on what you mention in your personal statement.
- The start is always the hardest thing to write, so I started with some stupid opening (it was 'Physics, the final frontier') and just started writing. You can always work on the opening later.

Recommendations for Reading, Online Lectures, etc.

It is important that you show that you love all of physics, not just the flashy bits that are on the news. So I recommend that you look at some easier undergraduate texts and lecture, below are some examples that I found quite useful.

- I believe that anything by Richard Feynman is pure gold, his undergraduate series 'The Feynman Lectures' allow an accessible introduction to university physics. It should also help your A-Level studies no ends. The first volume is not very mathematical but discusses many of the topics covered in first year. There are 2 books of 6 lectures called '6 easy pieces' and '6 no so easy pieces' and these are a good place to start. His book called 'Q.E.D' (quantum electrodynamics) is a really good introduction to his work at an accessible level and discusses things not found on the A-Level syllabus.
- The most useful book I found for practise for interview and PAT is called 'University Physics' by Sears & Zemansky. This covers many A-level topics, but mathematically and therefore the questions are much more akin to those that will be asked in the PAT and interview. Each chapter has about 100 questions and both pdfs of the book and solutions can be found online.
- There are many other popular science books out there. The others I remember reading are 'A Brief History of Time' by Steven Hawking and books by Frank Close on particle physics. Any large bookshop should have a popular science section that can give other ideas.
- There are many science magazines out there such as 'New Scientist', these are a very good way at keeping up with modern physics. Also remember to check for science related news.
- T.V. documentaries are also a good idea. I think that BBC's 'Horizon' series are by far the best, they are not just on physics, but if you look back at previous seasons you can find them on a broad range of physics topics. You can find many online on places like YouTube. My personal favourite is called 'The Pleasure of Finding Things Out' and is about Feynman. I find that many other documentaries are always on very similar topics and this can become a bit boring after a while.
- Many U.S. universities have online lecture causes. For general physics without too much maths the online Yale courses are very good, for a more mathematical course Leonard Susskin's 'Theoretical Minimum' is very good. For maths I think that M.I.T's online course are good and they cover a broad range of topics.

Aptitude Test

- Do the practise papers! The only way to get better at physics is to do it, online solutions can be found and the past papers can be found on the physics department's web page.
- Make sure to write all your working & to draw diagrams.
- The sort of topics that will come up are,
  1. Calculus, i.e. differentiation & integration
  2. Sketching functions, e.g. $f(x) = e^{(x-a)^2}$, $f(x) = e^{-x}sin(3x + \frac{\pi}{3})$. Note they can also ask about graph transformations.
  3. Expanding expressions using the binomial theorem.
  4. Geometry.
  5. Logarithms.
  6. Mechanics.
  7. Simple D.C. circuits, i.e. combining resistors, Kirchoff's laws, diodes, etc.
  8. Simple optics, i.e. diffraction, reflection, total internal reflection, superposition and diffraction gratings, etc. Note thin lens equations will probably not come up.
  9. They may also introduce new concepts and get you to do calculations with them. This can be a way to real ask more mathematical questions.

  Note this list is not exhaustive.
- You don't get a calculator so make sure mental maths is good enough. To practise I use to not take a calculator to maths to force me to do all maths in my head.
- It is important to understand what they are asking of you quickly and not to loose time if you don't know what they want (especially in the physics half). You can always come back later.
- If you haven't covered up to C4 make sure you can do all the calculus in this module as they may (& do) ask questions from any of A-Level maths.
- Note that the multiple choice questions have been removed for the paper.

Interview & Example Questions

Interview Advice

If applicants are good enough they will be invited to interview. The most important thing about the interview is to enjoy it (easier said than done). If you enjoy it, the tutors probably will and they will look on it favourably. It is a chance to sit down with someone else who is passionate about a subject that you hopeful love as much as them. If invited you will have two interviews at your first choice of college and then another at a randomly selected college.

- Always talk through what you are doing, the tutors want to see how you think.
- Prepare an answer to the question 'why do you want to study physics?' & 'want evidence (be it books or other things) do you have to back up your love of physics?'.
- The topics will be much the same as in the PAT, but they will be expanded on more as the tutors will try and test you.
- The aim is to push you to your absolute limit so don't be surprised if it is very hard.
- It will be a pressured environment and so you will be stupid mistakes (when plotting a graph I confused the x & y coordinates) don't stress about them the tutors will understand.
- The questions will be both on maths and physics.
- Get comfortable at talking about physics having practise interviews with teachers can be very helpful.

Example Questions

These are not real life questions, but are the sort of thing that could be asked. On the physics webpage there are also some recorded practise interviews.

1. 'Estimate the number of piano tuners in Chicago.' So the most important word is 'estimate' they don't want exact numbers, but they want you to think what is reasonable. They are looking for a order of magnitude calculation and how you think about something you probably have never thought about before. These questions are also a very good test of mental maths.

   Firstly Chicago is a large city, but I don't think it bigger than 10 million (about the size of London). So I guess that it is 5 million (pick nice numbers for easy maths as it happens its 2.7 million). If we assume one in a hundred households has a piano and that on average there are 4 people who live in a household. Therefore the number of households is $\frac{5{,}000{,}000}{4} = 1,250,000$ and so the number of pianos is $\frac{1{,}250{,}000}{100} = 12,500$. Now if we assume that a piano gets tuned every two years, so only $\frac{12{,}500}{2} = 6,250$ get tuned a year and a piano tuner works 300 days a year and he can tune 2 a day. Therefore he tunes 600 pianos a year and the number needed to tune is 6,250 a year, therefore there are approximately 10 ($\approx \frac{6{,}250}{600}$) piano tuners in Chicago.

   These are weird questions and require you guessing at values, if you get it wrong the tutors will tell you. Be able to back up your estimates, they want to see that you have some understand of the size of things.

2. 'Sketch the function $f(x) = e^{-x^2}$ and using this sketch $g(x) = ae^{-(x-b)^2} - c$. Were $a > 0$, $b > 0$ & $0 < c < a$ When doing the first part there are several important features to find

   - Any symmetry if it is an odd or even function.
   - Asymptotes.
   - Roots of the equation (were the line crosses the x axis).
   - The value of $f(0)$, i.e. were it meets the y axis.
   - Turning points.
   - Points of inflection.

   When doing the problem, I would find the different aspects in the above order. Firstly we note that the function is even, therefore there should be symmetry in the y axis. To find the asymptotes let $x \to \pm\infty$ (let x tend towards plus/minus infinity). We see as this happens in both cases that $f(x) \to 0$, therefore we have asymptotes on the line $y = 0$. For roots we must solve $f(x) = 0$, but for real values of x $e^{-x^2} > 0$ therefore it never crosses the axes and so there are no roots. If we let $x = 0$ then $f(0) = e^0 = 1$

   For turning points we need to solve $f'(x) = 0$ and then to classify any we need to use the second derivative test. So by the chain rule we get,

   $$f'(x) = -2xe^{-x^2} \tag{1}$$

   If we set $f'(x) = 0$ we get $x = 0$ as $f(0) = 1$ therefore the turning point is at (0,1). Note as $x \to \pm\infty$ $f'(x) \to 0$ therefore as f(x) approaches the asymptote the graph gets flatter and flatter (makes sense as the asymptote is flat). With a bit of thought the turning point should be a maximum as there is only one turning point and the asymptotes are straight lines at $y = 0$. But we can do the 2nd derivative test to prove that this is the case, differentiating again with the product and chain rule,

   $$f''(x) = 4x^2e^{-x^2} - 2e^{-x^2} \tag{2}$$

   Evaluating at x=0, we get $f''(0) = -2 < 0$ therefore it is a maximum as expected at (0,1). Seeing as we have already found $f''(x)$ we can also find any points of inflection where $f''(x) = 0$

   $$0 = 2e^{-x^2}[2x^2 - 1] \tag{3}$$

$$x = \pm\sqrt{\frac{1}{2}} \tag{4}$$

There are also points of inflection as $x \to 0$, but the main points of inflections are at $(\pm\sqrt{\frac{1}{2}}, e^{-\frac{1}{2}})$. Now we can sketch the graph.

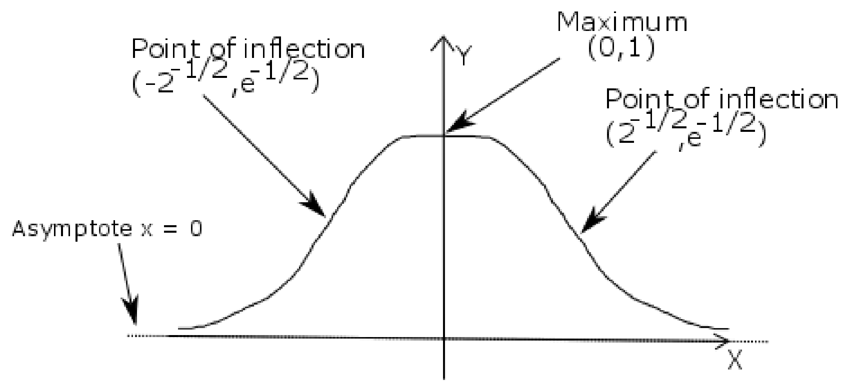

Fig. 1. Plot of $f(x) = e^{-x^2}$

This sketch may be reconsigned from statistics and is the basic for of a normal distribution. For the second half we have to recognise that all the new terms represent graph transformations. The $x - b$ represents a shift of the graph by an amount b and as $b > 0$ the graph is shifted to the right. Multiplying the exponential by a represents a stretch in the y direction by an amount a. The $-c$ term transform the whole graph down therefore the position of the maximum is at $(b, a - c)$ and as $c < a$ then the maximum is above the axis. We also have to shift the asymptotes down so that they are $y = -c$ and there for we now expect to have some roots. So solving $g(x) = 0$

$$-(x - b)^2 = ln\left(\frac{c}{a}\right) \tag{5}$$

$$x = b \pm \sqrt{ln\left(\frac{a}{c}\right)} \tag{6}$$

As $a > c$ this has real solutions, if we label the roots x_+ & x_- we can sketch the transformation and it is,

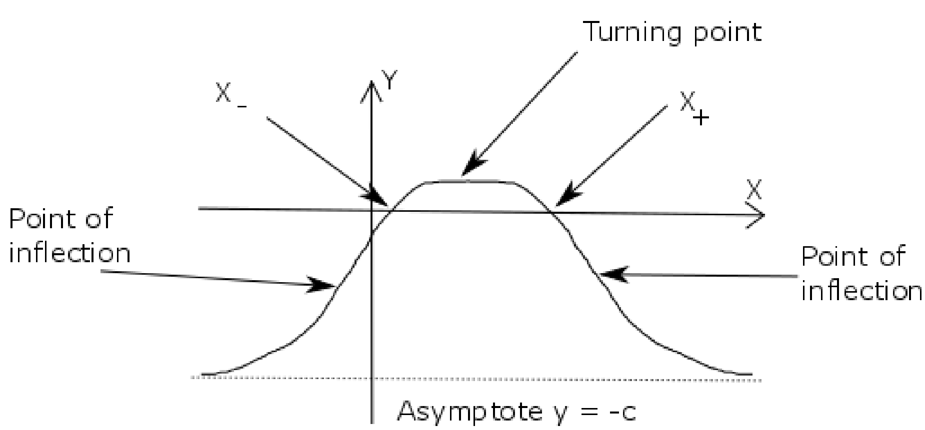

Fig. 2. The transformed Gaussian curve.

3. 'Find the maximum range of a projectile,ignoring any effects due to air resistance, launched over a flat surface with speed v and launched at angle θ.' Our aim here is to find the range as a function of θ and then differentiate to find the maximum.

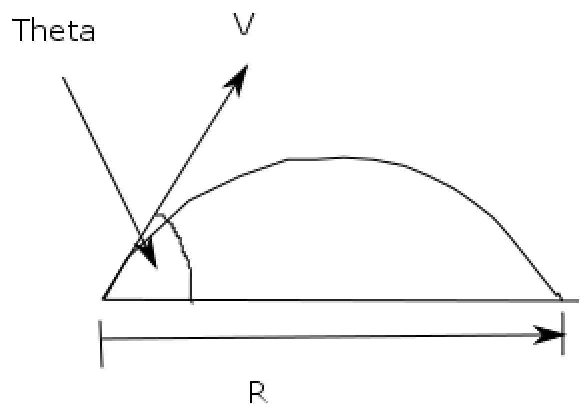

Fig. 3. Projectile diagram.

In the y direction we have acceleration due to gravity therefore,

$$y = vt\sin\theta - \frac{1}{2}gt^2 \tag{7}$$

The range is where the projectile hits the ground again, i.e. $y = 0$ so,

$$0 = t[v\sin\theta - \frac{1}{2}gt] \tag{8}$$

We can ignore the solution $t = 0$ as this is when the projectile is launched. Therefore,

$$t_r = \frac{2v\sin\theta}{g} \tag{9}$$

Where t_r is the time when the projectile lands again. As there is no acceleration in the x direction we can say,

$$R = vt_r\cos\theta \tag{10}$$

Subbing this into equation 9 we get,

$$R = \frac{2v^2\cos\theta\sin\theta}{g} \tag{11}$$

Now if we use the identity '$sin(2\theta) = 2sin\theta\cos\theta$' we get,

$$R = \frac{v^2 sin2\theta}{g} \tag{12}$$

Now differentiate w.r.t (with respect to) θ we get,

$$\frac{dR}{d\theta} = \frac{2v^2\cos(2\theta)}{g} \tag{13}$$

This equals zero when $\theta = \frac{\pi}{4}$ and this is the launch angle needed for maximum range. Note you could also note that equation 12 is maximum when $\sin 2\theta$ is maximum and this occurs when $\frac{\pi}{4}$.

Any Further Questions?

Please feel free to get in touch at kebleatlarge@outlook.com if you have any more questions about applying.