Physics Aptitude Test (PAT) Unofficial Extended Syllabus

University of Oxford Admissions Test

Physics, Engineering, Materials Science

PhysOx Initiative
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Contents

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1 Foreword

We know that many of you revising and working towards sitting the PAT will be working independently and so we decided to create this "extended syllabus" almost as a more specific checklist-type resource to aid your revision. In general, the PAT aims to test your understanding of the Physics and Mathematics you have come across at school but incorporates material across all of the boards. This might mean that you may have to look at some of the A2 material for some boards slightly before you are taught the content at school. Apart from little bits here and there it is important to note that the content is very much at the level of GCSE and A Level knowledge. The main thing to remember is that you want to aim to try and understand these very concepts at the most physical level possible and not just cram content/ learn mark schemes by memory as you might for A level/ GCSE exams. Part of this preparation is therefore spending some time looking through the Physics and picking these concepts apart but also doing past papers and challenging questions to consolidate your understanding. Good places to look would be the Maths Challenge/ Olympiad papers, the Physics Olympiad papers, Isaac Physics and also of course the PAT papers. We would also like to give a huge shout out to PMT notes and the question banks they provide - please use them, they are a wonderful source of revision for not only PAT prep but A Levels too!

Many people wonder when to start their preparation but there is no set answer and it also depends on what preparation you are doing. We would actually recommend looking at the papers fairly soon after you decide you want to do the PAT just so you know what you are aiming to be able to solve by the end and pacing yourself. Bear in mind that perhaps the bulk of your revision will be over the summer before (after your UCAS exams/AS Levels) as the PAT usually happens at the end of Oct/ start of Nov. That said, we would recommend doing some extra reading, asking your teachers further questions about the topics you learn about at school, etc. throughout year 12 as that could in a way kill two birds with one stone and do good things for your UCAS exams but also count as solid PAT revision. Don't leave the papers till the end, we know some people prefer to do that but sometimes familiarity really helps with learning how to approach the questions and also think deeper about the Physics. It is also very normal to find them incredibly difficult towards the beginning. It takes some time to get used to how to think about these types of questions but you will notice it does get slightly easier as you do them more so hold on tight!

Finally, this "extended syllabus" is not an official document. It was put together by a humble team of two, who have taught and/or marked the PAT before and have once upon a time done the exams themselves, as a more specific guide of topics you may want to make sure you have an intuition towards. We hope this is somewhat useful and wish you all the best with your revision!

2 Mathematics

2.1 Elementary Mathematics

Elementary Mathematics[1]	
Geometry	**2.1.1** Areas/perimeters of common 2D shapes, areas and volumes of spheres, prisms, cones, tetrahedrons **2.1.2** Tangents to circles, chords, arcs, sectors, area $A = \frac{1}{2}r^2\theta$
Probability	**2.1.3** Basic rules and notation: $P(A \cup B) = P(A) + P(B) - P(A \cap B)$, $\sum_i P_i = 1$, $P(A) + P(A') = 1$, $P(B \mid A) = \frac{P(A \cap B)}{P(A)}$ **2.1.4** Independent events: $P(A \cap B) = P(A) \times P(B)$ and $P(B \mid A) = P(B \mid A') = P(B)$ **2.1.5** Mutually exclusive events: $P(A \cap B) = 0$ so $P(A \cup B) = P(A) + P(B)$ **2.1.6** Venn diagrams and tree diagrams **2.1.7** Probabilities with and without replacement

[1] Consider anything from GCSE will be assumed. Will most likely mainly be featured in problem solving questions.

2.2 Algebra

Algebra		
Polynomials	2.2.1	Form of polynomial curves; how to factorise quadratics (completing the square, factorisation, significance of discriminant), cubics
Trigonometry	2.2.2	Basic identities $\frac{sin\theta}{cos\theta} = tan\theta$ and $sin^2\theta + cos^2\theta = 1$, awareness of sum and difference/half/double angle formula, sine/cosine rules
	2.2.3	Small angle approximations (from Maclaurin series)
Miscellaneous	2.2.4	Surds and indices, rationalising denominators
	2.2.5	Notation: $\mathbb{N}$, $\mathbb{Q}$, $\mathbb{R}$, $\mathbb{Z}$, subsets ($\subset$), and/intersection ($\cap$), or/union ($\cup$)
	2.2.6	Simultaneous equations
	2.2.7	Inequalities
	2.2.8	Circle equations $(x-a)^2 + (y-b)^2 = r^2$: circle center (a, b), radius r
	2.2.9	Partial fractions
Functions	2.2.10	Condition for odd $f(-x) = -f(x)$ and even $f(x) = f(-x)$ functions
	2.2.11	Inverse functions are reflections of the function along $y = x$

Algebra Cont.	
	2.2.12 Transformations: stretches/ compressions $y = af(x)$, $y = f(ax)$, translations $y = f(x) + a$, $y = f(x + a)$
	2.2.13 Parametric equations
Graph Sketching	**2.2.14** Approach for curve sketching: x,y intercepts, asymptotes, turning points (and nature), how graph behaves as $x, y \longrightarrow 0, \pm\infty$, symmetry
	2.2.15 Graphs of trigonometric functions ($sinx$, $cosx$, $tanx$, $cosecx$, $secx$, $cotx$, inverses)
	2.2.16 Graphs of e^x and lnx
	2.2.17 Intersections of curves
Logarithms and Exponentials	**2.2.18** Laws of logs and exponentials: $log_a x + log_a y = log_a(xy)$, $log_a x - log_a y = log_a(\frac{x}{y})$, $nlog_a x = log_a(x^n)$, and the equivalent laws for exponentials
Series	**2.2.19** Geometric Series: $a_n = ar^{n-1}$, $S_n = a(\frac{1-r^n}{1-r})$, $S_\infty = \frac{a}{1-r}$
	2.2.20 Arithmetic Series: $a_n = a + (n-1)d$, $S_n = \frac{n}{2}[2a + (n-1)d]$
	2.2.21 Binomial expansion $(a + bx)^n$ valid for $\lvert\frac{bx}{a}\rvert < 1$

2.3 Calculus

Calculus	
Differentiation	**2.3.1** First principles, as gradients/ rates of change
	2.3.2 Differentiating polynomials, trigonometric functions, exponentials, $ln x$
	2.3.3 Chain Rule, Product Rule, Quotient Rule
	2.3.4 Stationary points and their nature
	2.3.5 Maclaurin Series
Integration	**2.3.6** Fundamental theorem of calculus: integration as the inverse of differentiation, area under a curve
	2.3.7 Integration of basic polynomials, trigonometric, exponential, logarithmic functions
	2.3.8 Integration by substitution (e.g. $\int \frac{f'(x)}{f(x)} dx = ln f(x) + c$ and by parts (e.g. $\int ln x dx$); definite and indefinite integrals
	2.3.9 Simple separation of variables in first order differential equations (may come up contextually but will yield simple integral if it does).

3 Physics

3.1 Mechanics

Mechanics		
Fundamentals	3.1.1	Vectors and scalars
	3.1.2	The relationship between displacement (distance), velocity (speed) and acceleration, graphs
	3.1.3	Formulae for constant acceleration (SUVAT)
	3.1.4	Projectile motion
Forces	3.1.5	Interpretation of graphs: energy, field, force, acceleration, velocity, distance (gradients/areas)
	3.1.6	Vector addition of forces (and any vector quantity) and resultant forces
	3.1.7	Weight (W = mg, gravitational force in a uniform g field)
	3.1.8	Air resistance/ drag , frictional forces (more details later)
	3.1.9	Upthrust, the buoyancy force and Archimedes' Principle
Newton's Laws of Motion	3.1.10	Newton I, II, III
Circular Motion	3.1.11	Centripetal force ($F = m\omega^2 r = mv^2/r$)
	3.1.12	Centripetal acceleration (from $F = ma$, $a = \omega^2 r = v^2/r$)

Mechanics Cont.	
	3.1.13 Used in conjunction with the gravitational force, Coulomb force, component of weight (planes and cars on race tracks)
Frictional Forces	**3.1.14** Terminal velocity
	3.1.15 Drag $\propto v$ or v^2
	3.1.16 Coefficient of static friction μ_s and dynamic friction μ_d
	3.1.17 Free body diagrams e.g. objects stacked on top of each other, ladders on walls, etc.
Levers	**3.1.18** Moments (force x perpendicular distance from line of action of force)
	3.1.19 Torques and couples
	3.1.20 Conditions for equilibrium of a lever (no resultant force, no resultant torque - principle of moments)
	3.1.21 Double- and multiple-pivot systems
	3.1.22 The normal reaction force
	3.1.23 Inclined Planes
Springs and Materials	**3.1.24** Hooke's Law ($F = -kx = -k(l - l_0)$) and spring constant (also graphically)
	3.1.25 Area under F-x graph = Elastic Potential Energy ($EPE = \frac{1}{2}Fx = \frac{1}{2}kx^2$)

Mechanics Cont.		
	3.1.26	Energy transformations for vertical (KE, EPE, GPE) and horizontal (KE, EPE) mass-spring systems, Energy-x graphs
	3.1.27	Springs in series and parallel
	3.1.28	Young's Modulus, Stress, Strain (where Hooke's Law is obeyed)
	3.1.29	Terminology and graphical representation: Elastic limit, Yield Point, Plastic Deformation, UTS, Fracture Point
	3.1.30	F-x or Stress-Strain plots for brittle/ductile materials and hysteresis (e.g. in rubber, why?)
Conservation Laws and Energy	**3.1.31**	KE ($\frac{1}{2}mv^2$)
	3.1.32	GPE (mgh in the uniform field case)
	3.1.33	Other forms of energy: thermal, sound, electrical, chemical, etc.
	3.1.34	Energy - x graphs for the simple pendulum
	3.1.35	Conservation of energy
	3.1.36	Conservation of momentum (mass x velocity)
	3.1.37	Conditions for elastic and inelastic collisions
	3.1.38	Work done (Energy) = Force x distance moved in the direction of force = Power x time

3.2 Waves and Optics

Waves and Optics		
Fundamentals of Waves	**3.2.1**	Longitudinal and transverse waves, examples
	3.2.2	Terminology: amplitude, frequency, period, wavelength, speed, displacement
	3.2.3	Wave equation ($v = f\lambda$) and frequency = 1/time period
	3.2.4	Terminology: wave front, coherence, path difference, phase difference, superposition, interference
	3.2.5	EM spectrum and rough wavelength/frequency ranges
Reflection and Refraction	**3.2.6**	Law of reflection (angle of incidence = angle of reflection)
	3.2.7	Refraction, refractive index ($n = c/v$)
	3.2.8	Snell's Law ($n1sin\theta_1 = n2sin\theta_2$)
	3.2.9	Total internal reflection ($sin\theta_c = n_2/n_1$), prisms and optical fibres (3-refractive index system with core, clad, air)
Standing/ Stationary Waves	**3.2.10**	Terminology: nodes and anti-nodes, harmonics, fundamental mode
	3.2.11	Two fixed ends, two open ends and "open box" configuration allowed harmonics

Waves and Optics Cont.		
Diffraction	**3.2.12**	Rough idea of Huygens' Principle and what a wave does when it meets an obstacle/ gap, the optimal condition
	3.2.13	Single Slit diffraction and intensity pattern, Young's double slit ($\lambda = ax/D$), diffraction grating ($n\lambda = dsin\theta$)
	3.2.14	Slit/grating diffraction patterns for monochromatic vs white light
Ray Diagrams	**3.2.15**	Diverging and converging lens diagrams (assume thin lens: $1/u + 1/v = 1/f$), e.g. microscopes/telescopes
	3.2.16	Focal length and how being either side of the focal point can affect image through lens
	3.2.17	Magnification = image height/ object height (or can look at angles in ray diagram)

3.3 Electricity and Magnetism

Electricity and Magnetism	
Electricity and Circuits	**3.3.1** Key terms: current I (charge Q per unit time t), voltage V or potential difference (energy transferred W per unit charge), resistance R
	3.3.2 Key equations e.g. $Q = It$, $W = VQ$, Ohm's Law ($V = IR$) and when it applies, power $P = W/t$ and the other power equations in a circuit (e.g. $P = VI$)
	3.3.3 Circuit components, symbols, operation, IV graphs: batteries (and internal resistance in the case of the "real" cell/ battery, terminal p.d., emf), wires (ideal vs "real"), resistors (including variable resistors), filament lamps, diodes, LDRs, thermistors (usually just NTC expected), capacitors (see later)
	3.3.4 V, I, R in series and parallel circuits: Kirchhoff's laws (for current and voltage)
	3.3.5 Ideal voltmeter will have infinite resistance and ideal ammeter will have zero resistance, why?
Capacitors	**3.3.6** Derivation for exponential charging and discharging equations for Q,V,I with time t, boundary conditions ($t = 0, \infty$)
	3.3.7 Effect of dielectric on capacitance

Electricity and Magnetism Cont.

	3.3.8	Equations: $Q = VC$, parallel-plate capacitor $C = A\epsilon/d$
	3.3.9	Capacitors in series and parallel, rationale behind the relations
Electric Fields	**3.3.10**	Electric field around a charge (and diagrams), attraction and repulsion diagrams and Coulomb force ($F = kQq/r^2$), uniform electric field between two parallel plates ($E = V/d$, $F = qE$), electric potential and potential energy ($U = \int_\infty^r F(r)dr$)
	3.3.11	Photoelectric Effect, work function of materials
	3.3.12	Thermionic emission (e.g. electron guns) and acceleration of particles using an E field $W = QV$
Magnetic Fields	**3.3.13**	Magnetic fields generated around moving charge/ current-carrying wire, solenoids, force due to fields $F = Bqvsin\theta = BILsin\theta$, RH Thumb/Screw/Grip Rule
	3.3.14	Fields around magnets, attraction/repulsion, no magnetic monopoles
	3.3.15	Motor effect (Fleming's LHR) for when output is motion
	3.3.16	Generator effect, Faraday-Lenz's Law for induction

Electricity and Magnetism Cont.	
	3.3.17 Magnetic force acts perpendicular to direction of motion so does no work on particle, acts as centripetal force ($p = Bqr$)
	3.3.18 Transformers (power conservation), power loss in national grid

3.4 Natural World

Natural World		
Atomic Structure	**3.4.1**	Thomson's Plum Pudding Model, Rutherford's Gold Foil Experiment, Bohr Model; atom contains protons, neutrons and electrons (mass, charge), atomic and mass number
Astronomy	**3.4.2**	The Solar system, its constituents and relative positions (planets, moons, comets, asteroids)
	3.4.3	Parallax angles, units of arc seconds ($1/3600\ deg$) and arc minutes ($1/60\ deg$), astronomical unit
	3.4.4	Phases of the moon (new, waxing/waning crescent/gibbous, quarters, full)
	3.4.5	Eclipses (solar/lunar, partial/annular/total)
Gravitational Fields and Orbits	**3.4.6**	(Like E fields) Gravitational field around a point mass, force (= mass x field), potential energy $U = \int_{\infty}^{r} F(r)dr$, potential (= U/m); for a uniform field (near flat surface approx. $F = mg$); only attractive
	3.4.7	As centripetal force (equate), Kepler's Third Law (derivation)
	3.4.8	Polar and Geostationary orbits
	3.4.9	Escape velocity

3.5 Problem Solving

The official statement for this element of the syllabus is:

"Problems may be set which require problem solving based on information provided rather than knowledge about a topic."

The best revision to prepare yourself for this is essentially to do plenty of past papers, multiple times if possible so as to get used to the thinking style and just practice answering challenging physics questions. The following links may be useful for question practice:

- Isaac Physics
- Professor Povey's Perplexing Problems

  An excellent book with creative problems which will get the juices flowing. The link provided above allows viewing of a lot of the problems in the book but not all. If you would like to access the whole book, you can buy it here.

- The British Physics Olympiad Papers
- A Level Past Papers

  Don't underestimate the power of the good old A level past papers. We would also recommend going through the question banks in sites like PMT to really consolidate your understanding of the required topics, and then using past papers to practice questions which assimilate many topics together (usually the last paper you sit for most boards tend to feature more of these problem-solving-based questions).

- PhysOx Questions

  We have a selection of questions available on our website like the example interview practice questions and more will be added soon, so keep an eye out for additions to the PAT and Interview prep pages!

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